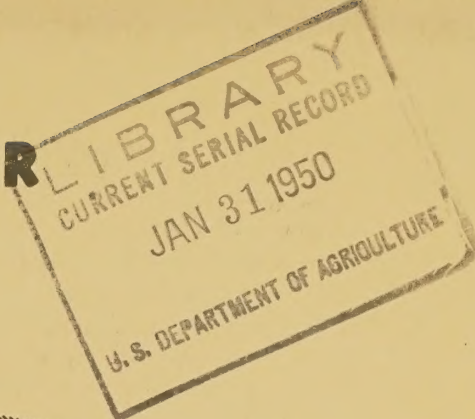


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CO-OP ELECTRIFICATION ADVISER TRAINING OUTLINE

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FARM AND HOME WIRING

REA

RURAL ELECTRIFICATION ADMINISTRATION

U.S. DEPT. OF AGRICULTURE

PURPOSES OF THIS OUTLINE

This is one of a series of outlines prepared by REA as an aid in planning and arranging training schools for co-op electrification advisers. Each outline deals with a power use subject or with some aspect of cooperative principles and practice or with a particular method or technique of getting information to people. These are the three principal fields in which electrification advisers need to be skilled. Each booklet contains both suggested subject matter and suggestions as to how the material might be presented, with an indication of a suitable time schedule. The booklet is

thus useful as a guide to committees in charge of training schools, as an aid to the instructors, and as a subject matter manual that may be distributed to participants at the close of a training session for study and future reference. Subjects available or in preparation are listed below by title and number. *It is suggested that committees planning such training schools keep in mind the need of training in all three types of subject matter and, insofar as practicable, make use of the outlines in a balanced combination.*

LIST OF SUBJECTS

An ORIENTATION OUTLINE (unnumbered) covers all three fields of information. It is to provide the subject matter for an initial school that will give co-op officials basic background information and an understanding of the nature and scope of the educational job to be done.

NO.	POWER USE SUBJECT	NO.	CO-OP SUBJECT	NO.	METHOD OR TECHNIQUE
1	Farm and home Wiring	100	Value of Co-op	200	Getting News to Members
2	Farm Motors		Membership		(Newsletters and State
3	Water Systems and	101	Integrating Power		Paper Columns)
	Plumbing		Use and Co-op	201	Using the Radio
4	Electric Ranges		Education	202	Co-op Reports and Non-
5	Laundry Equipment	102	The REA Program		periodical Publications
6	Poultry Production		and Co-ops	203	Making Effective Talks
7	Refrigerators, Home	103	The Electric Co-op	204	Demonstration Techniques
	Freezers, Walk-Ins		— What It Is	205	Methods and Results of
8	Small Appliances	104	The Co-op Movement		Adult Education
9	Dairying		— Here and Abroad		
10	Pig Brooding	105	Co-op Bylaws	206	Effective Meetings
11	Farm, Home and	106	Establishing Member		
	School Lighting		Ownership	207	Photography and Motion
12	Farm Shop	107	Assuring Member		Pictures
13	Pump Irrigation		Participation	208	Working with Newspapers
14	Garden Watering	108	Co-op Tax Status	209	Exhibits and displays
15	Electric Hotbeds	109	Annual Meetings	210	Working with Rural Youth
16	Elevating, cleaning	110	Co-op's Place in	211	Working with Community
	and grading farm crops		the Community		Organizations
17	Drying grain, hay, peanuts, etc	111	Cooperation Between Co-ops		
18	Heating, cooling, ventilating				
19	Cleaners, dish washers				
20	Kitchen planning				

UNITED STATES DEPARTMENT OF AGRICULTURE
Rural Electrification Administration
Applications and Loans Division

SUBJECT MATTER FOR
PROPOSED
WIRING SCHOOL
FOR
COOPERATIVE ELECTRIFICATION
ADVISERS

Revised

October 1949

SUGGESTED SCHOOL PROGRAM

On Which This
Subject Matter
is Based

FUNDAMENTALS OF WIRING

(1 day)

1. The parts of a wiring system.
2. Electrical and material terms.
3. Electrical behavior and effects significant in wiring.
4. The relation of adequate wiring to the operation of equipment.
5. Instruments and tools needed.
6. Review questions and practice period.

PLANNING WIRING SYSTEMS

(1 day)

1. Determining what electricity is to do on the farm.
2. Adapting the wiring to the individual working and living standards of the family.
3. Planning the location of outlets.
4. Basic wiring.
5. Devices for teaching planning to groups.
6. Preparing and using wiring plans.
7. Methods of estimating wiring costs.
8. Review and practice in planning.

THE WIRING

(2 days)

1. Sources of information on materials and techniques.
2. Wiring design and protection.
3. Polarity identification of system and circuits.
4. Branch circuits.
5. Services, feeders and service drops.
6. Grounding.
7. Types of wiring materials and their uses.
8. Rules and regulations.
9. Inspection and reinspection.
10. Methods of inspection.
11. Review and practice in wiring and inspection.

SUGGESTED OUTLINE FOR WIRING SCHOOL PROGRAM

FIRST DAY - Morning Session		Leader	Pages
9:00	Introductory Remarks	Chairman	
9:15	Introduction of Participants	Chairman	
9:30	Parts of Wiring Systems and Electrical Terms	State College Repr. or Qualified Elec. Contractor	1-9
10:30	Recess		
10:45	Electrical Behavior a. Ohm's Law	Ext. Agr. Engr.-St. College REA Hq. or Field Repr.	10-12
12:00	Recess for Lunch Afternoon Session		
1:15	Application of Ohm's Law	Same as preceding topic	
2:30	Safety Practices	State Job Training Instr.	13
3:15	Demonstration Equipment a. Voltage Drop b. Services	REA Hdq. or Field Repr. Ext. Agr. Engineer	14-18
5:00	Adjourn		
SECOND DAY - Morning Session			
8:30	Announcements	Chairman	
8:45	Review of Problems a. Voltage Drop b. Services	Same as for Demonstration	
10:00	Recess		
10:15	Planning Wiring Systems a. Determination of Uses b. Adoption of Individual Needs c. Location of Outlets (General discussion, not actual layout)	Ext. Agr. Engineer or Qualified Elec. Contr. or REA Repr.	22-23
11:15	General Discussion	Chairman	
12:00	Recess for Lunch Afternoon Session		
1:15	Teaching Aids for Planning Preparation of Wiring Plans Methods of Estimating Costs	State College Repr. or Qualified Elec. Contr.	28-30 31-33
3:00	Recess		
3:15	General Review and Discussion	Panel	
5:00	Adjourn		
THIRD DAY - Morning Session			
8:30	Announcements		
8:45	Question and Answer Period a. Written Questions submitted by Advisers (1 each)	Panel	
10:00	Recess		
10:15	Farm House Wiring Helping Farm Family Plan Wiring	State College Repr. or REA Field Repr.	38-42 35-36
12:00	Recess for Lunch Afternoon Session		
1:15	Sources of Information a. National Electrical Code b. REA Farmstead Wiring Specifications	REA Hdq. or Field Repr.	37
3:00	Recess		
3:15	General Review and Discussion	Panel	
5:00	Adjourn		

FOURTH DAY - Morning Session		Leader	Pages
8:30	Announcements	Chairman	
8:45	Inspection Program	Qualified Inspector or REA Hdq. or Field Repr.	43
	a. General Requirements and Electrical Contractors' Responsibility		37-38
	b. Types of Wiring Methods		
10:30	Recess		
10:45	Review	Chairman or Panel	
12:00	Recess for Lunch		
	Afternoon Session		
1:15	Farmstead Building Wiring	Agr. Engr. - State College Extension Specialist	
	a. Water Supply		
	b. General Barn, Grain and Hay Storage		
	c. Poultry and Hog Houses		
	d. Dairy Barns and Farm Shop		
3:00	Recess		
3:15	Establishing Wiring Program	Manager or REA Field Repr.	
4:15	General Discussion	Panel - All Discussion Leaders	
5:00	Adjourn		

In order that the presentation and discussion of subject matter for proposed Wiring School for Cooperative Electrification Advisers may be presented in a logical and orderly sequence, the above suggested outline has been prepared. The listed topics and time allotted to each are merely suggestive. The page numbers refer to the specific topics covered in "Subject Matter Packet."

It is hoped that the State Power Use and Member Education Committee will find the use of this outline and subject matter most expedient and helpful in planning the Wiring School for Electrification Advisers.

WIRING FUNDAMENTALS

I. THE PARTS OF A WIRING SYSTEM

A farmer's wiring system begins where the wires from the transformer on the hi-line pole reach his building or his yard pole. The electric current on the hi-line is spoken of as primary current. The current that comes from the transformer and travels through the farmer's wiring system is spoken of as secondary current.

In order to thoroughly understand the farmer's wiring system some knowledge of the generation, transmission, and distribution of the primary current is needed.

A. The Primary Current

1. Generated as three-phase current by:
 - a. Steam power
 - b. Diesel power
 - c. Water power
2. Transmitted as three-phase current which is divided into single-phase current for distribution.
3. Most co-ops buy wholesale power.
 - a. Most co-ops buy three-phase current at their substations
 - b. Some co-ops buy single-phase current
 - c. Current graphically represented by three-phase sine curve and single-phase sine curve
4. Single-phase current only available at most farms.
 - a. Primary voltage at transformer - 6900 to 7200 volts.

B. The Secondary Current

1. Transformer delivers secondary current at 120 volts and 240 volts.
2. The service drop leads from the transformer to the meter loop.
 - a. Two wires provide 120 volt current.
 - b. Three wires provide 120 volt current and 240 volt current.
3. The meter loop leads from the service drop to the building service wires if it is on a yard pole, or to the load center if it is on a building - usually the house.
 - a. Contains either 2 or 3 wires to conform with the service drop.
 - b. The meter is placed in it.
 - c. If on the yard pole it may include a main service switch.
 - d. Always grounded.
4. Farmstead distribution.
 - a. From yard pole preferably
 - b. Often from house
 - c. Each building service grounded
 - d. Size and number of wires to each building determined by:
 - (1) Amount of current to be carried
 - (2) Distance
 - (3) Switch controls
 - (4) 2 wires for 120 volts
 - (5) 3 wires for 120 and 240 volts

5. Building distribution.

- a. Service entrance wires lead to load center (also known as distribution panel, and may be the branch circuit fuse box).
- b. The load center.
 - (1) May be in a single box if there are 6 or less branch circuits.
 - (2) Main fuses and disconnect switch is separate box from branch circuit fuses if there are more than 6 branch circuits.
 - (3) Size of main fuses depends on amperage to be used on the farm.
 - (4) Size of branch circuit fuses depends on size of wires in branch circuits and the use of the branch circuits.
 - (5) Load center must be readily accessible.
- c. Overload control
 - (1) Fuses
 - (2) Circuit breakers
- d. Branch circuits
 - (1) Lighting circuits
 - (a) Fused for 15 amperes
 - (b) Minimum size wire No. 14
 - (c) 120 volts
 - (2) Appliance circuits
 - (a) Fused for 20 amperes
 - (b) Minimum size wire No. 12
 - (c) 120 volts
 - (3) Special circuits
 - (a) Range circuit
 - (i) 35 or 50 amperes
 - (ii) 120 and 240 volts
 - (iii) Wire size generally No. 6 depending on amperage and distance
 - (b) Water heater circuit
 - (i) Usually 20 amperes but depends on size of heating elements
 - (ii) 240 volts
 - (iii) Wire size depends on amperage and distance. Preferably never smaller than No. 12.
 - (c) Large power circuit
 - (i) Amperage to fit motors and power used.
 - (ii) 240 volts
 - (iii) Wire size depends on amperage and distance.
 - (d) Low voltage circuits for doorbells, furnace controls, etc.
 - (i) Receives power through special transformer connected to an appliance or light circuit,
 - (ii) 10 to 24 volts
 - (iii) Wire size usually No. 18.

e. Outlets

- (1) Light outlets
 - (a) Located on ceilings or walls
 - (b) Connected through an outlet box
 - (c) Fixture held by a fixture holder
- (2) Switch outlets
 - (a) Not counted for estimating load on circuit
 - (b) Usually located on wall by door
 - (c) Connected through an outlet box
 - (d) Types of switches
 - (i) Toggle type only
 - (ii) Mercury
 - (iii) Single pole
 - (iiii) Three way
 - (iiiii) Four way
 - (e) Cover plates
 - (i) Single switch
 - (ii) Multiple switch
 - (iii) Brown or ivory
- (3) Convenience outlets
 - (a) Distributed in room
 - (b) Height depends on room and use
 - (c) Connected through outlet box
 - (d) Types
 - (i) Single
 - (ii) Double (duplex)
 - (iii) Multiple
 - (iiii) Polarized
 - (iiiii) Special purpose such as radio, clock
 - (iiiiiii) Dust proof
 - (iiiiiif) Weatherproof
 - (e) Cover plates
 - (i) Single, double, and multiple
 - (ii) Brown or ivory

II. ELECTRICAL TERMS

A. Method and Material Terms Significant in Wiring

1. Service Drop - The wires between the line pole or yard pole and the building, which bring the electricity to the building. The service drop ends at the point where the wires first attach to the building.
2. Service Entrance Conductors - The wires between the service drop and the main switch or over-current protection in a building. The service entrance conductors connect to the service drop just outside and clear of the building walls.
3. Service Insulators - Spools of glass, porcelain or other insulating material that hold the building end of the service drop in place on the building and prevent electrical contact of the service drop and the building. They may be attached to the building singly or in groups on metal racks.
4. Service Entrance Head - A metal-hooded fitting having bushed holes through which the service entrance conductors pass from the outside into a metal raceway or service entrance cable. It is placed on the outside of the building near the service insulators and excludes moisture from the inside of the raceway or cable.
5. Service Equipment - The main switch and overload protection equipment at which the service entrance conductors terminate after passing into the building. The over-current protection consists of fuses or circuit breakers. The entire assembly is enclosed in a metal cabinet.
6. Service Ground - The assembly of wire, straps, connectors, clamps, and grounding electrode or rod used to permanently connect the neutral wire of the service entrance conductors and the metal enclosure of the service equipment to moist earth.
7. Feeder - A set of wires used to carry current from the service equipment to a branch circuit cabinet at a remote location. It is used to eliminate having all branch circuits start at the service equipment.
8. Over-Current Protection - Circuit breakers or fuses used to open the circuit when the current reaches a predetermined value. Required in each ungrounded service or feeder wire, and in each ungrounded branch circuit wire.
9. Circuit - A general term indicating an assembly of wires and other conductors so arranged as to provide a continuous path for an electric current from the point of origin to the point of use and back to the point of origin.
10. Branch Circuit - A circuit originating at the branch circuit over-current protection.
11. Lighting Branch Circuit - A branch circuit supplying current to lights only. Colloquially, the term is often incorrectly used where combination lighting and appliance branch circuit would be correct.
12. Appliance Branch Circuit - A branch circuit having no permanently connected lighting fixtures, and supplying current to permanently wired appliances or attachment-plug outlets.

13. Combination Lighting and Appliance Branch Circuit - A branch circuit supplying current to lighting fixtures and to appliances or attachment plug outlets.
14. Motor Branch Circuit - A branch circuit supplying current to motors only.
15. Distribution Center - Usually synonymous with service equipment. It is the assembly of equipment at the point where the building wiring divides into feeders, or branch circuits, or both.
16. Main Distribution Center - The first distribution center reached by the wiring as it comes into a building.
17. Feeder Distribution Center - A distribution center supplying current to feeders.
18. Branch-Circuit Distribution Center - A distribution center supplying current directly to branch circuits. Includes the branch circuit fuses or circuit breakers.
19. Outlet - A point on a wiring system at which current is furnished to current-consuming equipment. Switches are sometimes called outlets, but the context of the discussion must be known to know whether they are included in the term. For example, contractors count switches when bidding on a wiring job by the outlet, but switches are not counted when determining under the National Electrical Code the number of outlets that may be served by a circuit. Best use of the term would always make clear whether switches are included.
20. Lighting Outlet - An outlet for the connection of a lighting fixture or a drop cord.
21. Receptacle Outlet - An outlet for the connection of attachment-plugs on cords. Often called convenience outlet, duplex outlet, etc.
22. Raceway - A channel for holding wires or cables, which is solely for this purpose. The term raceway is preferred to conduit which is often used with the same meaning. Raceways may be of metal, wood, or insulating material, and the term includes rigid metal conduit, flexible metal conduit, electrical metal tubing, cast-in-place raceways, under-floor raceways, surface metal raceways, surface wooden raceways, wireways, busways, and auxiliary gutters.
23. Rigid Metal Conduit - A steel pipe (raceway) through which wires or cables may be pulled after the conduit is in place.
24. Flexible Metal Conduit - A circular flexible metal raceway through which wires or cable may be pulled after it is in place.
25. Electrical Metal Tubing - Often called thin-walled conduit. Similar to rigid metal conduit except of thin-walled steel joined by threadless fittings.
26. Surface Metal Raceway (Metal Molding) - A metal channel with a metal cap, in which the wires or cable are placed.
27. Surface Wooden Raceway (Wood Molding) - Similar to surface metal raceway except made of wood and containing partition for separation of the individual wires.
28. Armored Cable (in interior wiring) - Two or more rubber-covered, separately insulated, wires built into a spirally-wound, flexible, metallic covering. Usually, locally known by trade-names such as B-X.

29. Non-Metallic Sheathed Cable - Two or more rubber-covered separately insulated wires built into an outer insulating fibrous sheath. Usually, locally known by the trade-name Romex.
30. Flexible Tubing (Loom) - A flexible tube of insulating fibrous material that is placed around individual, insulated wires to give mechanical protection.
31. Cleat - An insulator, usually porcelain, which holds one or more wires at a definite spacing from a surface or from each other, and which is fastened to the surface with nails or screws.
32. Knob - Similar to a cleat, but is held in place by a single nail or screw. Holds a single wire. It provides definite spacing between the wire and the surface to which it is fastened.
33. Tube - A hollow cylindrical piece of porcelain with a head or shoulder on one end. It is used to provide additional insulation and protection to a wire passing through a wall, floor, ceiling, joist, stud, etc.
34. Coupling - A short piece of raceway used for connecting two longer pieces. The longer pieces screw or are otherwise fastened into the coupling.
35. Nipple - A straight piece of rigid metal conduit not more than 2 feet long and threaded on each end.
36. Bend - A short curved piece of rigid conduit or other metal raceway which serves to connect the ends of two lengths of conduit that are at an angle to each other.
37. Elbow (Sharp Bend) - A bend of comparatively short radius.
38. Fitting - An accessory (such as a locknut or a bushing) to a wiring system that performs primarily a mechanical rather than an electrical function.
39. Conduit Fittings - The accessories necessary for the completion of a conduit system, such as boxes, bushings, and access fittings.
40. Cabinet - An enclosure with swinging doors.
41. Cutout Box - An enclosure for surface mounting and having swinging doors or covers fastened to and telescoping with the walls of the enclosure.
42. Conduit Box - A metal box for installation in conduit to allow pulling the wires, making connections, mounting devices, etc.
43. Pull Box - A metal box with a blank cover for installation in conduit to allow pulling the wires through. It may be installed at the end of raceway to provide for distributing the wires.
44. Junction Box - A metal box with a blank cover installed in cable or raceway which provides a place for the connection and branching of the enclosed wires.
45. Knockout - A small portion of the wall of a box or a cabinet so made that it may be readily removed by striking with a hammer. It provides access for wires and for the attachment of conduit, cable, etc.

46. Splice (Straight-through Joint) - The connection in series of two lengths of wire or cable.
47. Insulating Joint - A connection for mechanically fastening adjacent pieces of conduit, pipes, rods, etc., together while keeping them electrically insulated from each other.
48. Lampholder (Socket), (Lamp Receptacle) - A device for mechanically supporting an electric lamp (incandescent bulb or fluorescent tube) and electrically connecting it to the circuit.
49. Receptacle (Convenience Receptacle) - A device installed in a receptacle outlet for mechanically holding an attachment-plug of a portable lamp or appliance and which provides the electrical contact between the outlet and the plug.
50. Fuse Holder (Cutout Base) - The device in an electric circuit that holds the fuse and provides the electrical connections for its terminals.
51. Sealable Equipment - Equipment which may be sealed or locked in such a way that unauthorized persons cannot operate it or have access to live parts.
52. Plug - A device installed on the end of a cord to provide a means of connecting the cord to a receptacle.
53. Current Tap - An assembly in one device of a plug and two or more sockets for plugs in such a way that when the device is plugged into a receptacle two or more plugs may be connected to it allowing several appliances to be used at one outlet.
54. Hickey - A fitting used to mount a lighting fixture in an outlet box or on a pipe or stud. It permits the fixture wires to be brought out through the fixture stem.
55. Snake (Fishing Wire) - A wire which is pushed through a race-way, a partition or other closed space and is used for drawing wires through the space.
56. Binding Screw (Binding Post), (Terminal Screw), (Clamping Screw) - A screw which connects a conductor to the terminal of a piece of electrical apparatus.
57. Pendant - A fitting suspended from overhead by a flexible cord.
58. Cord Grip - A device which grips a cord as it enters an accessory and prevents the terminals from receiving tension on the cord.
59. Fixture Stud (Stud) - A fitting used in mounting a lighting fixture in an outlet box. The stud is fastened to the box and the fixture is fastened to the stud by a hickey.
60. Crowfoot - A fitting used to mount a lighting fixture. It holds the fixture away from the mounting surface. The use of outlet boxes has made it obsolete.

II. ELECTRICAL TERMS CONTINUED

B. Electrical Terms Significant in Wiring

1. Ampere - A unit of rate of electrical flow. (When one coulomb of electricity passes per second, the electric current is one ampere).
2. Volt - A unit of electrical force. (A measure of difference in electrical potential. Voltage determines the insulation needed.)
3. Ohm - A unit of electrical resistance. One ohm is the resistance through which one volt will produce a current of one ampere; two ohms is the resistance through which one volt will produce a current of one-half ampere; etc.
4. Watt - A unit of power. Most commonly used to indicate the power of electricity. One horsepower is 746 watts. With direct current and with alternating current which lacks inductance and capacitance the number of watts of power is equal to the product of the volts multiplied by the amperes. For example: A device operating on 115 volt current and consuming 5 amperes would be using 575 watts (5×115). With alternating current having inductance or capacitance the number of watts of power is equal to the product of three things: (1) Volts, (2) Amperes, and (3) Power Factor. For example: A fluorescent lamp operating on 115 volt current and consuming $1/2$ ampere at a power factor of 80 percent would be using 46 watts ($115 \times 1/2 \times .80$).
5. Kilowatt - A unit of power. Equals 1000 watts. Approximately $1-1/3$ horsepower.
6. Kilowatt hour - A unit of work. Commonly used to indicate the amount of work done by electricity. Approximately $1-1/3$ horsepower hour, 2,654,000 foot pounds or 3,415 B.T.U.s. The work done by 1 kilowatt of power in one hour, one half kilowatt in 2 hours, 2 kilowatts in one-half hour, four kilowatts in 15 minutes, etc.
7. Watt hour - A smaller unit of work than kilowatt hour. 1,000 watt hours equal 1 kilowatt hour.
8. Insulator - Any substance used to restrict the flow of electricity to a practical minimum. No known substance will completely prevent a flow of electricity, but some have exceedingly high resistance. All substances can be located on a scale of electrical conductivity varying from low conductivity (high insulation) to high conductivity (low insulation). Most substances fall in the intermediate ranges on this scale. Those that lie in the extreme lower areas of the scale are more or less consistently classed as insulators. Those that are above this extreme lower area but not in the uppermost area may be classed either as insulators or conductors, depending on their significance in the matters being discussed. An insulator is merely a poor conductor, and there is no line of demarcation between poor conductors and better conductors that can be applied in all situations. Substances such as porcelain, glass, rubber, mica, dry wood, and dry cloth are good insulators for many purposes.

9. Conductor - Any substance used to allow the flow of electricity. Substances vary from very good conductors to very poor conductors. The good conductors are consistently classed as conductors. Those that are not so good depend on their significance in the matters being discussed for their classification as conductors or nonconductors. Silver, copper, aluminum, and iron are good conductors. Most wet or damp substances are fair conductors. In electric wiring, the most common conductors are copper wires.
10. Ground - An electrical connection which maintains a fixed electrical potential. In a wiring system, a ground is a connection to the earth so that the grounded portion of the wiring is fixed at the same electrical potential as the earth. This prevents any voltage between the grounded portion of the wiring and the earth, and makes it impossible for the voltage between the ungrounded portion of the wiring and the earth to exceed the voltage between the grounded and the ungrounded portions of the wiring.
11. Electromotive Force (abbreviated e.m.f.) - The electrical potential between the poles of a power source. Measured in volts. While voltage can be measured between any two conductors of electricity or between any two places on the same conductor, the term electromotive force applies only to the potential (voltage) across the line at the source.
12. Ohm's Law - This is the most important law of electrical behavior for people working with electrical appliances. It is most commonly written as an algebraic equation. By transposing, the equation takes any one of the following forms:

$$(1) E = IR$$

$$(2) I = \frac{E}{R}$$

$$(3) R = \frac{E}{I}$$

in which E is the electrical potential measured in volts, I is the electric current measured in amperes, and R is the resistance measured in ohms. E, I, and R respectively are used to designate volts, amperes, and ohms because by wide usage they have had international adoption. For purely local use, the letters V, A, and O might be substituted for the standard symbols E, I, and R. Ohm's Law is a mathematically exact expression for all electric current which are not affected by induction or capacitance. Thus it is always literally true for nonfluctuating direct currents. It is only approximately true for alternating current since there is always some induction and capacitance when alternating current is used. With lighting and heating devices that depend on resistance for their operation, it is so nearly exact that the error is negligible for practical purposes. With motor driven equipment, fluorescent lighting, and other equipment involving considerable inductance or capacitance the error may be considerable. Ohm's Law may be written so as to be exact for all currents but the algebraic equation then becomes quite complicated.

III. ELECTRICAL BEHAVIOR AND EFFECTS SIGNIFICANT IN WIRING

A. Relation of Volts, Amperes, and Watts - In any electric circuit that lacks both inductance and capacitance, the amount of power is the product of the potential and the rate of flow. Thus we have the formula Watts = Volts X Amperes. Even with alternating current, which is always affected to a limited extent by inductance and capacitance, this relationship is usually sufficiently accurate to be used for practical purposes. The error can be neglected unless the power factor is quite low. To correct for the effects of inductance and capacitance, we can write the equation:

$$\text{Watts} = \text{Volts} \times \text{Amperes} \times \text{Power Factor.}$$

B. Heat - Ohm's Law gives us the equation $E = IR$ in which E is synonymous with Volts and I is synonymous with Amperes in the equation Watts = Volts X Amperes. Therefore, we can substitute values from one equation in the other. Thus we get:

$$(1) \quad W = V \times A$$

$$(2) \quad W = AO \times A = A^2O$$

$$(3) \quad W = V \times \frac{V}{O} = \frac{V^2}{O}$$

Since the work done by an electric current in a building wire appears in the form of heat, we can see from equation (2) that the heating of a wire is directly proportional to its resistance (ohms) and is proportional to the square of the current (amperes). If the resistance of a wire is doubled, and the current remains the same, the heat will be doubled. If the current is doubled and the resistance remains the same, the heat will be multiplied four times. Increasing the current three times increases the heat nine times. From this we can see that if the current in a wire is multiplied by 3, we have to reduce the resistance of the wire to one-ninth of its former value to keep the power losses (in the form of heat) in the wire the same. Replacing a 15 ampere fuse with a 30 ampere fuse multiplies by 4 the amount of heat produced in the building wire by the maximum current that would not blow the fuse.

The simple equation $W = A^2O$ explains some of the dangers in short circuits, arcs, etc. A short circuit means reduced resistance in the whole circuit. Ohm's Law shows that this will increase the amperes. If the short circuit reduces the resistance by one-tenth, the amperage will increase 10 times and the heat produced in any specific section of the wiring will be increased 10 times. An arc glows because the increased resistance at that point increases the heat in the same proportion.

- C. Voltage Drop - The proper operation of most equipment is determined by the amperes through it. Ohm's Law tells us that amperes are determined by voltage and resistance. The resistance is built into the equipment when it is manufactured. The voltage is determined by the transformer and the wiring. Wiring that causes a significant voltage drop between the transformer and the appliance reduces the amperage through the appliance. From the equation $W = A^2R$, we can see that the rate that the appliance does its full load job decreases in proportion to the squares of the amperage as the amperes decrease. Smaller wires and longer wires are the most common sources of increased resistance in wiring.

Here is a mathematical calculation illustrating the conditions and effects of voltage drop.

- (1) Assume the voltage at the transformer is 120V.
- (2) Assume that the appliance is built to draw 10 amperes at 115V, which is normal full load operation.
- (3) Assume that we have a choice of either wire X or wire Y in the wiring circuit which feeds the appliance. Wire X has a resistance of $1/2$ ohm. Wire Y, being a smaller wire of the same material, has a resistance of 3 ohms.
- (4) Applying Ohm's Law ($R = \frac{E}{I}$) to the appliance gives us the resistance of the appliance:

$$R = \frac{115}{10} = 11.5 \text{ ohms.}$$

- (5) The total resistance of the appliance plus wire X is 11.5 + .5 or 12 ohms.
- (6) The total resistance of the appliance plus wire Y is 11.5 + 3 or 14.5 ohms.
- (7) By applying Ohm's Law ($I = \frac{E}{R}$) to the appliance and wire X we find the amperage if wire X is used.

$$I = \frac{120}{12} = 10 \text{ amperes}$$

10 amperes is correct for normal operation.

- (8) By applying Ohm's Law ($I = \frac{E}{R}$) to the appliance and wire Y we find the amperage if wire Y is used.

$$I = \frac{120}{14.5} = 8.3 \text{ amperes}$$

This is less than the 10 amperes required for normal operation.

- (9) Since the work that an electric appliance can do is proportional to the squares of the amperes flowing through it ($W = A^2R$), we can determine how much less work this appliance can do if connected through wire Y than if connected through wire X.

$$10^2 = 100$$

$$8.3^2 = 68.8$$

Since 68.8 is roughly 2/3 of 100, the capacity of the appliance is reduced roughly 1/3 by the use of wire Y.

- (10) The relative reductions in current flow and work done by the appliance should be noted. A reduction in current of 17% reduced the work over 31%. The difference between 31% and 17% is waste electricity used in heating wire Y and paid for by the consumer but for which no benefit is received. This waste is in addition to possible damage to the equipment as a result of the low voltage caused by wire Y.

D. Calculating Voltage Drop - There are several methods of calculating rather accurately the voltage drop in a circuit. As a usual thing, it is best to start with a table giving the resistance of a specified length of the wire. Table 18 of the National Electrical Code does this for our more common wire sizes. Here is data taken or calculated from this table:

Wire Size (AWG)	Ohms Resistance per 1,000 feet of single wire	Ohms Resistance per 1,000 feet of 2 or 3 wire cable
18	6.510	13.020
16	4.094	8.188
14	2.575	5.150
12	1.619	3.238
10	1.018	2.036
8	.641	1.282
6	.410	.820
4	.259	.518
2	.162	.324
1	.129	.258
0	.102	.204
00	.0811	.162
000	.0642	.128
0000	.0509	.102

When the resistance of a specific length of the wire is known, the determination of the voltage drop is merely a matter of applying Ohm's Law. Let's take an example: Suppose appliances drawing 15 amperes are to be served by a circuit of No. 12 wire 60 feet long. From the table, we know that a circuit of No. 12 wire 1000 feet long has a resistance of 3.238 ohms. Therefore, a circuit 60 feet long would have a resistance of .194 ohms.

$\left(\frac{60}{1000} \times 3.238 = .194\right)$. Applying Ohm's Law ($E = IR$) we get
 $E = 15 \times .194$ or $E = 2.9$ volts drop.

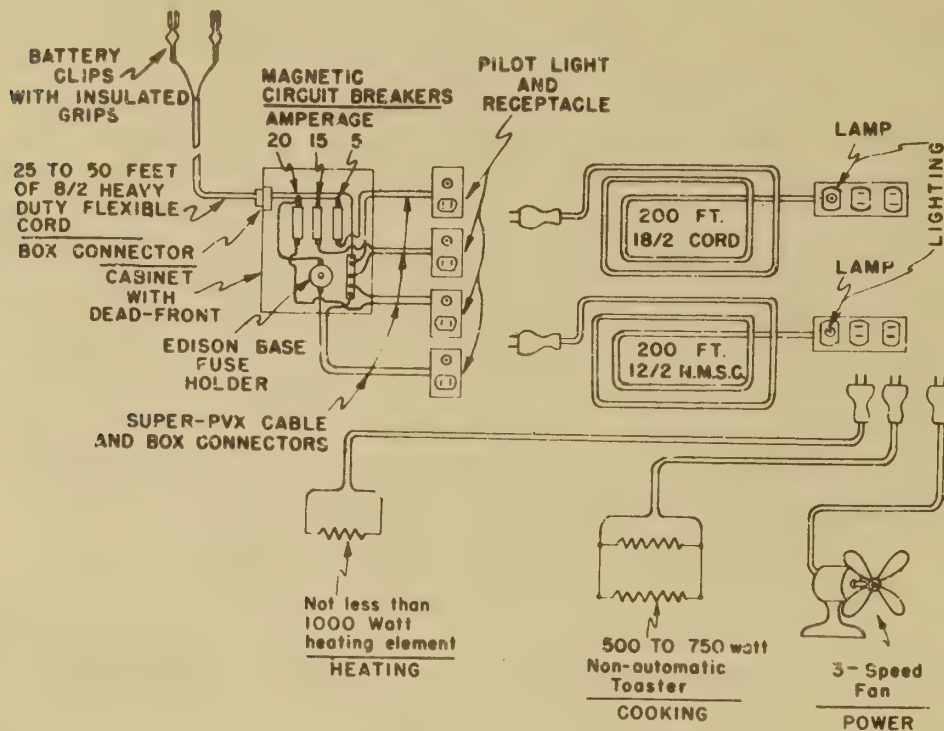
- E. Shock - Electric shock results from amperage through a body tissue. It can vary in intensity from a mild tingle through paralysis, to actual destruction of the tissue. No fixed rule can be given which divides safe from unsafe shocks. Some tissues can stand safely greater shocks than others. The physical conditions of people vary so that a shock that is safe for one person is fatal to another. However, one rule can be stated: All shocks from ordinary 115 volt building wiring circuits are potentially dangerous. We are often asked, "Is 115 volt electricity dangerous?" The technically correct answer is that voltage, regardless of its dimension, is not dangerous in itself. It is amperage that causes shock. But by looking at Ohm's Law ($I = \frac{E}{R}$) we can see that voltage is an important factor in determining amperage. If the resistance stays constant, amperage (and shock) will increase as voltage increases. If the voltage stays constant, amperage (and shock) will increase as the resistance decreases. It is not uncommon for people to be in situations such that the resistance of an electric circuit through them is low enough so that the amperage of a 115 volt current will cause death.

Maximum protection from shock from wiring comes from the correct combinations of isolation, insulation, and grounding to fit each situation. Of these three, grounding is probably most misunderstood and most commonly incorrectly done. Inadequate grounding has resulted in many deaths. Grounding and insulation are not mutual substitutes.

The National Electrical Code suggests that the insulation on circuits of No. 14 or No. 12 wire have a resistance of 1,000,000 ohms, and that the insulation on circuits of larger wire up to 50 amperes capacity have a resistance of 250,000 ohms.

Grounding conductors should always have current carrying capacity at least equal to that of the wiring devices that they protect. The resistance of a ground must always be low enough to open the over-current protection in case of a short circuit to the ground. The National Electrical Code specifies a maximum resistance of 25 ohms. An even lower resistance is better.

IV. DEMONSTRATION OF THE EFFECT OF VOLTAGE DROP ON THE OPERATION OF ELECTRICAL EQUIPMENT



- A. The schematic diagram shown above and the photograph, assembly drawing and bill of materials on the following pages illustrate equipment which may be assembled and used for demonstrating the relation of adequate wiring to the operation of electrical equipment. Three things may be demonstrated with the set-up shown:
- (1) The effects of voltage drop on the operation of electrical equipment.
 - (2) Some of the causes of voltage drop.
 - (3) The operation of fuses and circuit breakers in providing over-load protection.

B. The Demonstration Equipment

The diagram illustrates the following equipment:

- (1) Twenty-five to 50 feet of heavy-duty flexible cord for connecting the demonstration to a source of electricity. The cord shown is 8/2 or 10/2 but 12/2 may be satisfactorily used. One end of this cord is connected to the line terminals of load center equipment. The other end is connected to a heavy duty 2-prong plug for connection to any receptacle source of 110-120 volt power. A short length of heavy duty cord may be added with a cord receptacle on one end and battery clips with insulated grips on the other. This supplementary piece of cord would provide for using the clips to connect directly to the service drop or the building load center when the circuits supplying the convenience receptacles lack capacity for the demonstration.

- (2) Load center equipment. The equipment shown here is not standard; it contains 3 magnetic circuit breakers and one Edison base fuse holder. This combination makes it possible to demonstrate the action of both circuit breakers and fuses.
- (3) Four branch circuits, each ending in a combined pilot light and convenience receptacle. The pilot light is merely for showing that the circuit is energized. It should be red.
- (4) Two hundred feet of 18/2 flexible cord with one end attached to an appliance plug and the other end connected to a multiple convenience receptacle (E) and a lamp base (D).
- (5) Two hundred feet of 12/2 nonmetallic sheathed cable with one end attached to an appliance plug and the other end connected to a multiple convenience receptacle and a lamp base.
- (6) Two 7½ watt, white incandescent lamps for use in the lamp bases connected to the 18/2 cord and 12/2 cable.

Equipment Needed Which is Not Illustrated

- (1) Appliances for loading the circuits and on which the effects of the voltage drop will be apparent. For the best demonstration, the appliances will be needed in pairs. For example, there might be 2 identical fans, 2 identical nonautomatic toasters, and 2 identical radiant heaters with 1000 watt elements. Other useful appliances might include a 1/4 hp motor with a simple, homemade prony brake, 2 identical glass coffee makers, 2 identical nonautomatic hand irons, 2 identical vacuum cleaners with manometer tubes to show their suction, etc.
- (2) A supply of different sizes of Edison base fuses for use in the fuse holder in the load center, and a supply of different sizes of Fuestrons (not Fusestats) for use in the same holder.

C. Demonstrating the Cause of Voltage Drop and its Effect on the Operation of Equipment

Before any demonstration of this type is given before a group of people it should be gone through completely in private to make sure that the equipment is properly assembled and that the differences being shown are apparent enough to be clearly seen by observers. Small electrical loads on wires produce relatively small voltage drops and the demonstrator must know in advance the amount of load needed, in terms of the equipment that he is using, to produce an effect that is clearly apparent.

- (1) The demonstration equipment is explained to the audience so that the audience will understand what is happening as the demonstration proceeds.
- (2) The feeder cable is connected to a source of 110 to 120 volt electricity with the circuit breakers open and no fuse in the fuse holder. The attention of the audience is called to the fact that there is no visible change.
- (3) The 15 ampere and the 20 ampere circuit breakers are closed. The pilot lights on the two circuits connected through those breakers will light immediately. The audience should clearly see this and realize that the lighted pilots mean that those two circuits are energized.
- (4) The 200 feet of 18/2 cable is plugged into one of the energized circuits and the 200 feet of 12/2 nonmetallic, sheathed cable is

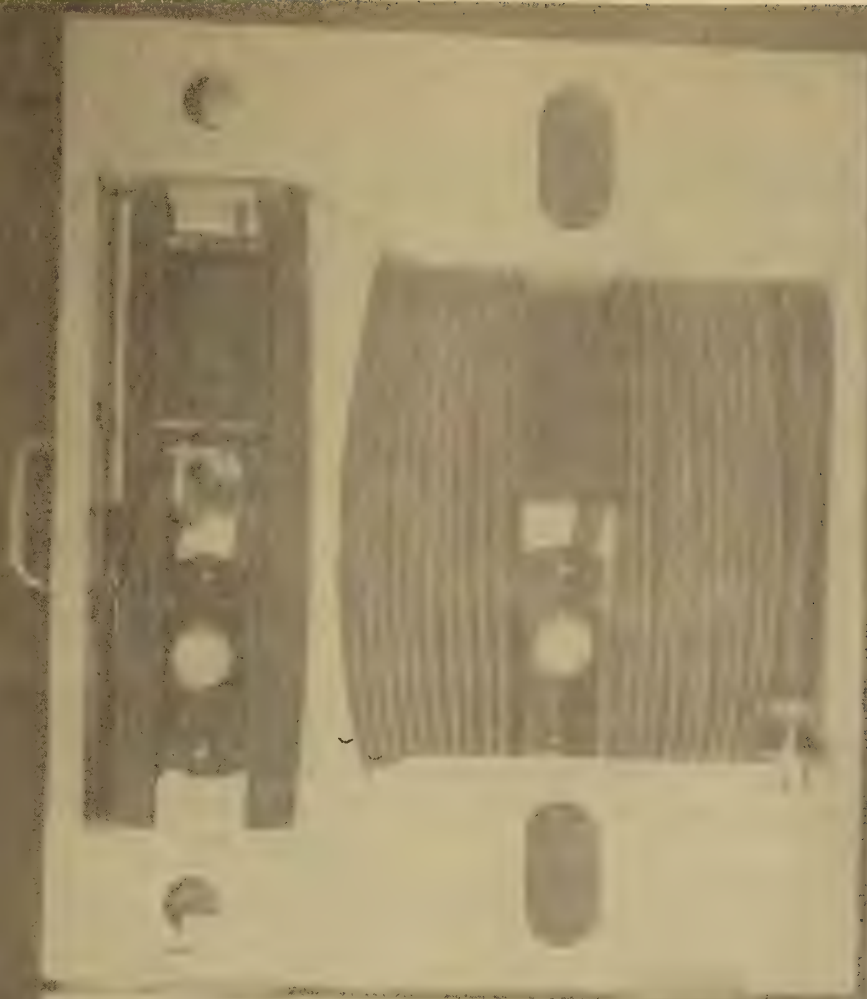
plugged into the other. The two $7\frac{1}{2}$ watt, white bulbs on the other ends of these wires will then light, showing the audience that both of these coils of wire are energized. There will be no apparent difference in the brilliance of the two $7\frac{1}{2}$ watt bulbs and this should be called to the attention of the observers. This indicates that both 18/2 cord and the 12/2 cable adequately supply the $7\frac{1}{2}$ watt bulbs.

- (5) One of the two identical fans is plugged into the receptacle on the end of the 18/2 cord and the other into the receptacle on the 12/2 cable. Both fans appear to run normally and there is still no apparent difference in the brilliance of the $7\frac{1}{2}$ watt bulbs.
- (6) One of the 1000 watt heating elements, which may be in a hot plate, a radiant heater, or some other device with a visible element, is plugged into the outlet of the 18/2 cord and the other identical element into the outlet on the 12/2 cable. A noticeable dimming of the $7\frac{1}{2}$ watt light on the 18/2 cord will be evident. If the fans are running on a slow speed, it will be noticed that the fan connected to the 18/2 cord is running definitely slower than the other one. After the two heating elements have had time to heat, it will be noticed that the element connected to the 18/2 cord is obviously less hot than the other. The light, the fan, and the heating element on the 12/2 cable all appear to be operating normally. Apparently the small wire is overloaded.
- (7) Add the two identical, nonautomatic toasters to the groups of appliances already connected. Call the attention of the audience to the fact that the $7\frac{1}{2}$ watt bulb on the 18/2 cord is now giving definitely poor light by comparison with the other bulb. After the heating elements have had time to adjust to their new temperatures, let the audience see that the 1000 watt element on the 18/2 cord is now performing even poorer by comparison with the other one than it was previously. Place slices of bread simultaneously in the two toasters. When the bread in one begins to smoke, turn the slices in both. When one of them smokes again, remove the slices and let the audience compare the results of operating toasters on a loaded small wire and on an equally loaded larger wire.
- (8) Give the individuals in the audience an opportunity to place their hands on the two coils of wire (18/2 cord and 12/2 cable). Call to their attention that the excess heat in the coil of 18/2 wire was produced by electricity used in the wire rather than in the appliance, and that although it registered on the meter, no benefit was received from it.
- (9) Explain to the group that conditions were deliberately exaggerated in the demonstration; that on their farms they will seldom have situations as bad as was demonstrated by the 18/2 wire, but that they do have bad situations due to inadequate wires between and in their buildings. Make clear to the group that this is not a demonstration of how to wire, but that it merely shows the causes of voltage drop and the effects of voltage drop on the operation of equipment. The noticeable heat in the coil of 18/2 wire can be used to point out the dangers of overloading circuits.

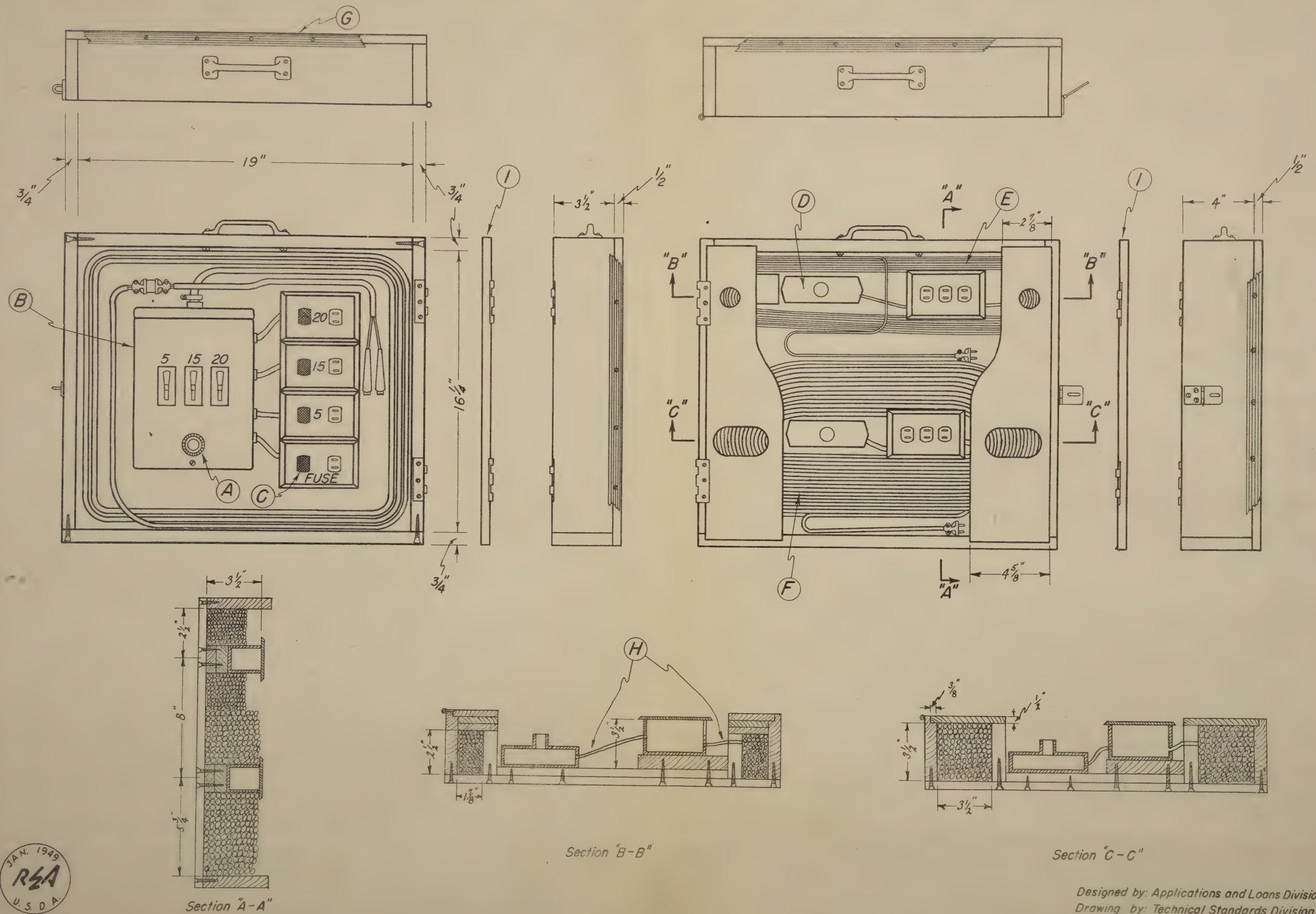
- (10) There are many possible variations to this demonstration. Many different types of equipment might be used to load the wires. Portable voltmeters might be plugged into the receptacles at the ends of the two coils of wire to show the greater drop in the 18/2 wire. This might be good before high school and vocational classes, but before adult farm groups, the actual operation of the equipment is far more effective than readings on meters with which the groups are not very familiar. Light meters and bulbs larger than the $7\frac{1}{2}$ watt ones might be used to show differences in light output, but, again, meters are much less effective teaching to people not familiar with them than actual visible differences in the brilliance of the bulbs. The fans have been suggested to show the effect of low voltage on motor driven equipment. This often can be more effectively demonstrated by a small motor equipped with a simple prony brake. Only one motor would be used. It would be alternately plugged into the outlets on the 18/2 cord and the 12/2 cable to show differences in starting power and break-down torque.
- (11) The audience should be fully aware that the 18/2 cord used in this demonstration is not suitable for building wire, that the 18/2 cord and 12/2 cable are compared because larger sizes could not be overloaded enough to show the differences when fed through most building wires, and that the 18/2 cord is not protected by the circuit breaker used. The demonstrator should not leave the heavy load on the 18/2 cord long enough to destroy the cord.

D. Demonstrating the Operation of Fuses and Circuit Breakers

- (1) For this demonstration the coil of 12/2 cable is not used since it could not be overloaded through the 20 ampere breaker or a 20 ampere fuse. The receptacle on the end of 18/2 cord is used for the addition of load to cause the breakers to trip and the fuses to blow. The plug on the other end of the 18/2 cord is plugged into the receptacles on the respective branch circuits as each breaker or fuse is being demonstrated. A 5 ampere fuse or breaker provides proper protection for the 18/2 cord.
- (2) Proper 5 ampere protection should be demonstrated first to show how this prevents dangerous overloading of the wire. Larger fuses and circuit breakers should then be used to show how they allow loads beyond the safe limit.
- (3) Connecting through a 5 ampere fuse a motor which draws somewhat less than 5 amperes while running will demonstrate that fuses that would give running protection to motors will not allow them to start. Replacing the fuse with a 5 ampere Fueston will show how time-lag fuses can be used to give this protection. Circuit breakers provide the needed time-lag, and this can be demonstrated.



VOLTAGE DROP AND PROTECTIVE DEVICE DEMONSTRATION PANEL



JAN. 1949
R&A
U. S. D. A.

Designed by: Applications and Loans Division
Drawing by: Technical Standards Division

LOW VOLTAGE AND PROTECTIVE DEVICE DEMONSTRATION PANEL

List of Materials

Lumber:

2 pieces	3/4" x 3-1/2" x 17"
1 piece	3/4" x 3-1/2" x 19"
1 piece	3/4" x 3-1/2" x 20-1/2"
2 pieces	3/4" x 4" x 17"
1 piece	3/4" x 4" x 19"
1 piece	3/4" x 4" x 20-1/2"

Plywood:

2 pieces	1/2" x 4-1/2" x 17"
4 pieces	1/2" x 17-3/4" x 20-1/2"

Note: Interior blocking to be cut as required. The lumber used in the actual construction is 3/4" boards and 1/2" plywood. Other thicknesses may be used as long as the inside dimensions are not changed.

Other cabinet materials:

2 each	Handles (brass or other metal) with bolts.
4 sets	1-3/4" x 2-1/2" loose pin, butt hinges.
13 ft.	3/4" x 3/4" metal corner mold.
Wood screws as required.	
Hasps or other fasteners as required.	

Electrical Equipment:

1 each	Circuit breaker cabinet, dead front, (modified) with Edison base fuse holder.
1 each	Circuit breaker, 20 ampere
1 each	Circuit breaker, 15 ampere
1 each	Circuit breaker, 5 ampere
1 box (mixed sizes)	Fuses, 5 - 20 amperes
1 box (mixed sizes)	Fusetron
4 each	Convenience receptacle with pilot light and one outlet.
2 each	Battery clips, rated 40 amperes, with insulated grips.
3 each	2 prong plug, heavy duty.
1 each	Plug receptacle, heavy duty.
2 each	Multiple convenience receptacle (3 outlets)
2 each	Lamp base
2 each	7-1/2 watt white incandescent lamp
25-30 ft.	10/2 or 12/2 heavy duty flexible cord
200 ft.	18/2 flexible cord (rubber covered lamp cord)
200 ft.	12/2 non-metallic sheathed cable (Super-PVX or equivalent used with these dimensions of box)

PARTS LETTERED ON DRAWING

- A - Edison base fuse holder
- B - Circuit breaker cabinet, dead front (modified)
- C - Pilot light (red lens)
- D - Lamp base
- E - 200 Feet 18/2 flexible cord
- F - 200 Feet 12/2 non-metallic sheathed cable
- G - Aluminum corner mold
- H - Interior connections - convenience outlet to
lamp holder
- I - Panel covers

WIRING DEMONSTRATION PANEL

The drawing and bill of materials on the following page may be used to construct a wiring demonstration panel which represents a cross-section view of a two-story house with basement. It's purpose is to illustrate how a house is wired and to show each part of the wiring installation in its relation to all of the other parts.

Since wiring is generally concealed, only the surface mounted parts can be observed in a farm home. It will readily be seen that all of the connections from the weatherhead on the service entrance to every light or switch outlet and back to the ground rod can be examined in the display panel. They all work just as though they were installed in a regular size house.

The spaces between the plywood panels and the sides of the box represents the wiring channels between wall studing where house wiring conductors are placed. The only concealed wiring is to the convenience outlets. The conductors to those outlets are visible at the points where they pass through the false back of the box. These should be pointed out to every audience. If necessary, the back panels can be removed to show these circuits and the outlet box connections.

Where a wiring test is available each circuit can be rung out to be sure it is properly polarized and connected. One outlet can be improperly connected so the test set will indicate faulty wiring.

A six circuit distribution panel with one spare circuit is recommended. Only four connected circuits are shown here. A fifth circuit could be run to illustrate a laundry power supply in the basement if desired.

The audience should be encouraged to examine the panel, ask questions, and to operate the switches and circuit breaker toggles on the distribution center.

V. TOOLS NEEDED BY ELECTRIFICATION ADVISERS

Note: Items marked with an asterisk (*) indicate tools advisers may need at training conference.

A. Miscellaneous Tools

1. *Side Cutting Electrician's Pliers (Klien)
2. *Mechanics Pliers
3. *Skinning Knife
4. *Screw Drivers
 - (a) *8" Shank
 - (b) *6" Shank
 - (c) *4" Shank
 - (d) *2" Shank
 - (e) *Phillips Screw Driver
5. *Set 8 Allen Hexagonal Wrenches
6. *Hack Saw (6" to 12" size) with extra package of fine tooth blades.
7. *Cold Chisel
8. *Pin Punch
9. *Prick Punch
10. *Claw Hammer
11. Ball Pien Hammers (1 lb. and 2 lb.)
12. Carpenters Brace (with ship carpenters bit - 2 sizes)
13. Key Hole Saw
14. Carpenters Saw (Cross-cut)
15. Carpenters Saw (Rip)
16. Set Metal Cutting Bits for Carpenters Brace (1/4"; 3/8"; 1/2")
17. Carpenters Square
18. Carpenters Level (short or samll level square permissible)
19. Set 3 wood chisels (1/4"; 1/2"; 1")
20. 1 Expansion Type Wood Bit (3/4" to 1-1/2")
21. *Adjustable Wrenches (6" and 10")
22. *Small Pipe Wrench (10" Stilson)
23. *Wiring Slide Rule
24. *Tool Box or Tool Kit for Tools

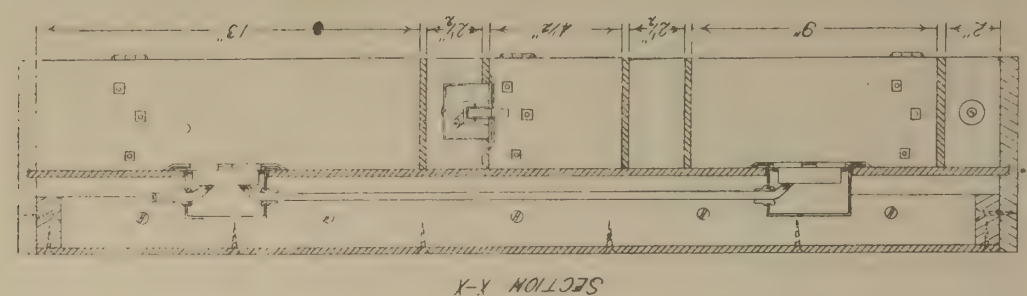
B. Electrical Tools

1. *Volt meter, pocket size 2" x 4" x 5 1/2" with a 300 volt or a (150-300 volt) scale
2. Ammeter, pocket size 2" x 4" x 5 1/2" with 10/20 ampere scale
3. Watt hour meter on a portable base with convenience receptacle and a 6 foot extension cord
4. *Electric soldering iron (200 watts)
5. Small electric drill (for 1/4" bits)
6. Large electric drill (for 1/2" bits)
7. Set 20 metal bits for above drills 1/32" to 1/2"
8. *Testing lamp (115-230 volts)
9. Hook-on Ammeter (150-300 volts, 0-150 amps)
10. Wiring test set.

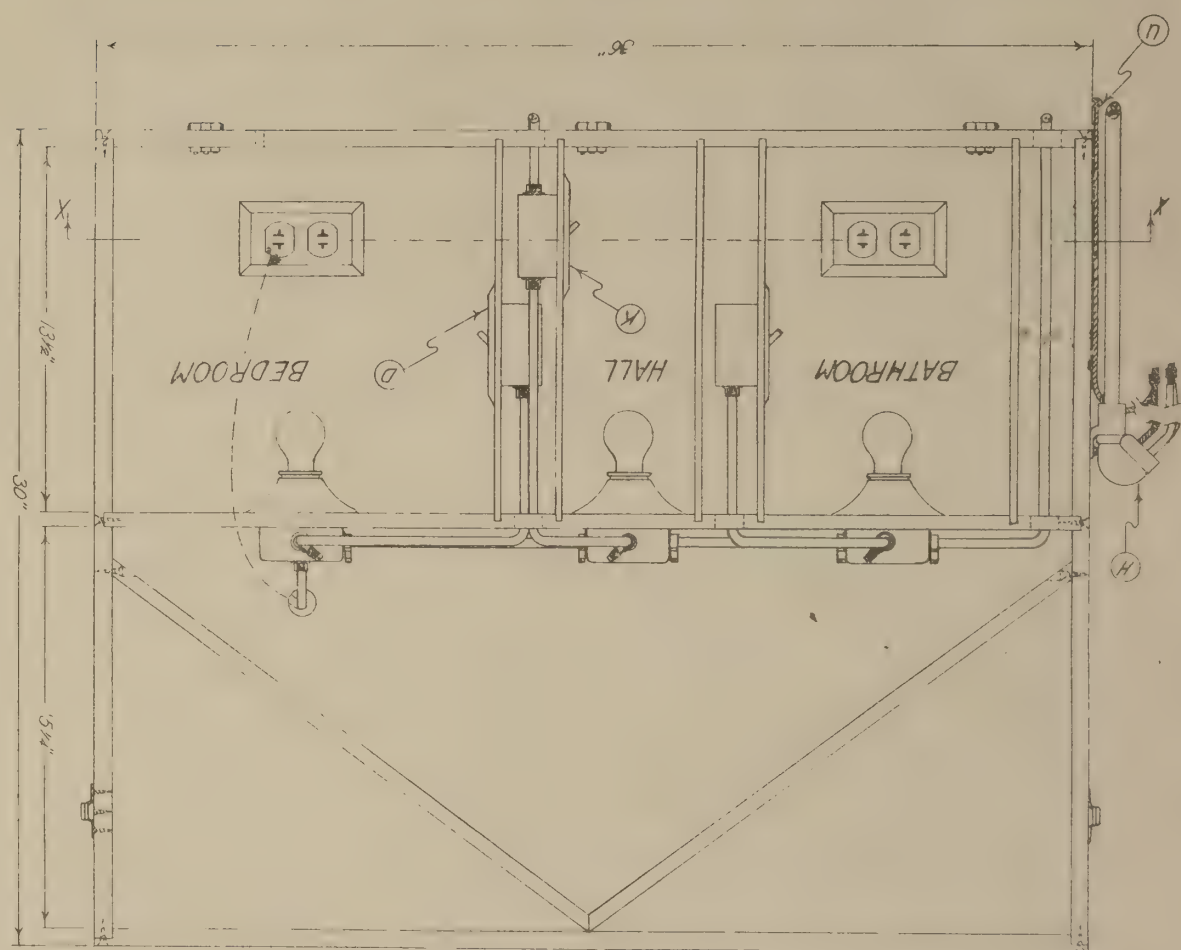
C. Teaching Tools

1. *Ruler
2. *Compass
3. *Protractor
4. *Graph Paper (cross-section)
5. Wiring Diagrams
6. Drawing Set
7. Drawing Table
8. 30°-60° triangle (10" or 12")
9. 45° triangle
10. T Square
11. *Drawing Board (approximately 14" x 20")
12. *Clip Board.

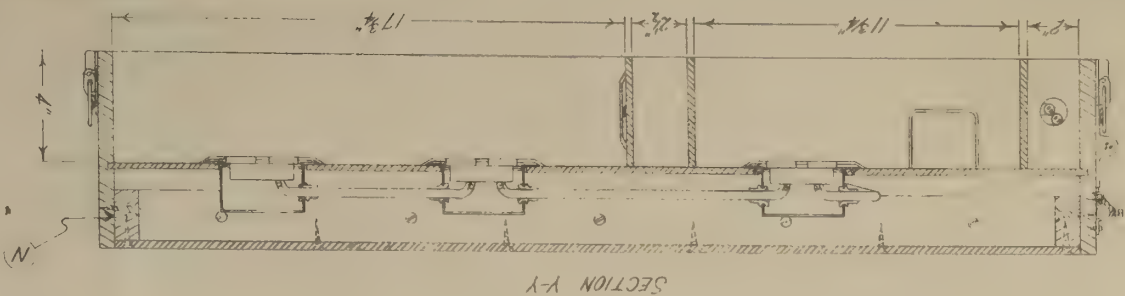
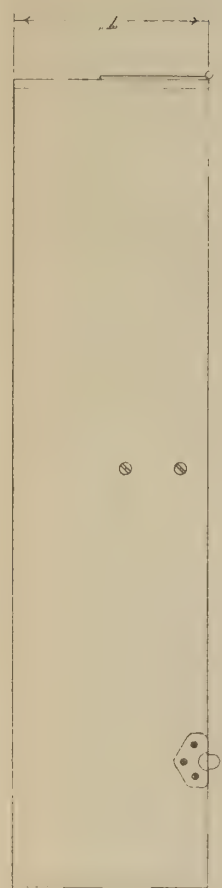
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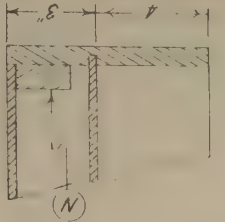
SECTION X-X



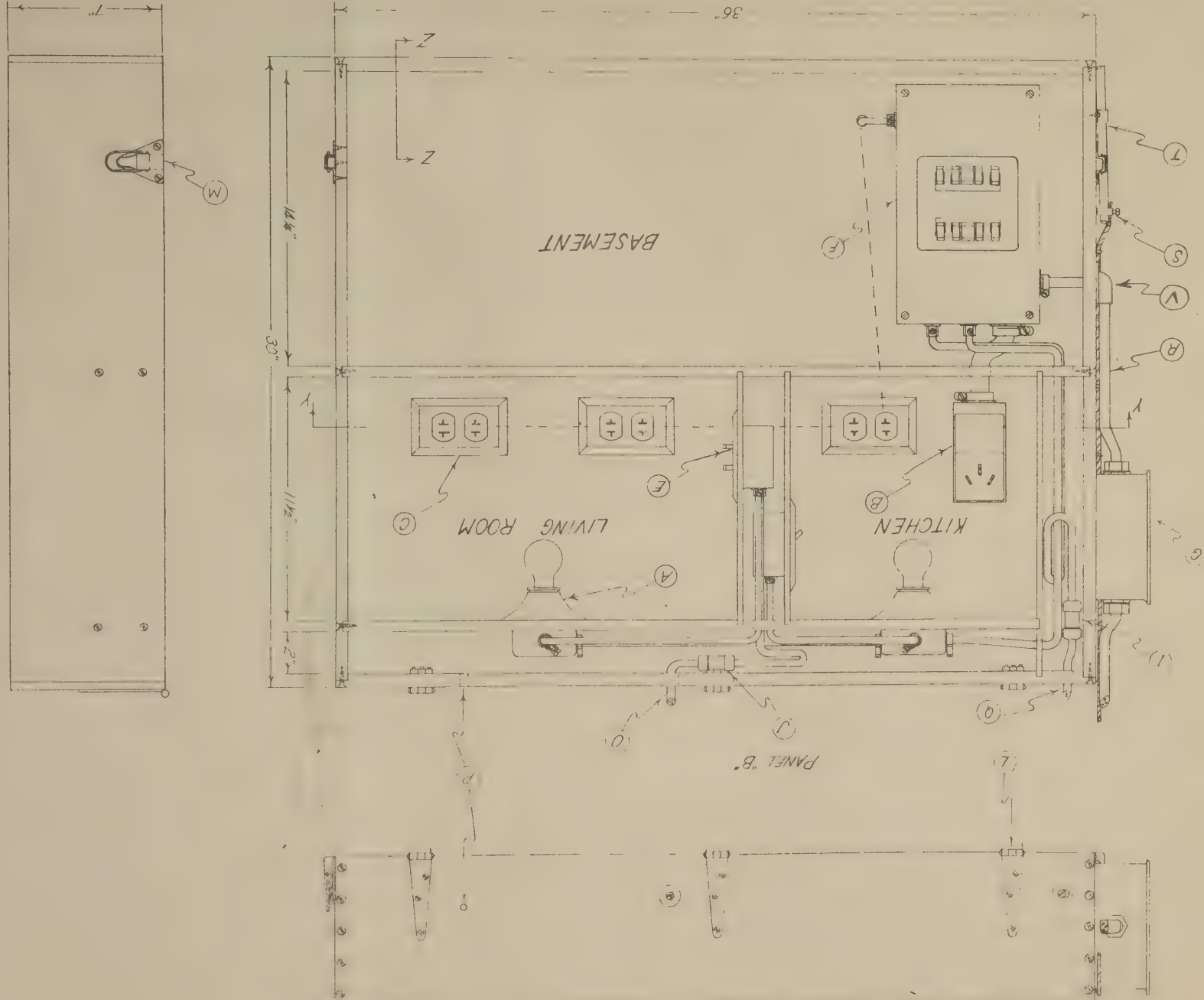
PANEL "A"



SECTION Y-Y



SECTION Z-Z



HOUSE WIRING DEMONSTRATION PANEL
 DESIGNED BY DANIEL W. TEARE
 APPLICATION AND LEADS DIVISION
 DRAWN BY TECHNICAL STANDARDS DIVISION
 DATE: APRIL 14, 1949

LIST OF MATERIALS

ELECTRICAL EQUIPMENT

Number	Name
5	Lamp holder
5	Outlet box, 3-1/4" x 1-1/2" with cable connectors
1	Range outlet and connector
5	Duplex convenience receptacle
5	Wall switch boxes, 2" deep with cable connectors
5	Wall switch boxes, 1-1/2" deep with cable connectors
3	Switch, single pole
1	Switch, despard combination (1 SP and 1 3-way)
1	Switch, 3-way
1	Circuit breaker panel, dead front, 70 amp.capacity
2	Circuit breaker, 15 ampere
2	Circuit breaker, 20 ampere
1	Circuit breaker, 25 ampere
1	Circuit breaker, 50 ampere
1	Meter socket, standard
1	Weather head
1	Sill plate, 6/3 cable
1	Connector, cord, twist lock, midget (2-wire)
1	Connector, cord, twist lock, midget (3-wire)
3	Connectors, cable, for 5/8" knockout
2	Connectors, for 6/3 cable
1	Ground rod (cut short) and clamp
5	Bulbs, incandescent
As required	Cable, 2-wire, non-metallic sheathed
As required	Cable, 3-wire, non-metallic sheathed
As required	Cable, SE Style U.
As required	Ground wire, #6 soft drawn

MISCELLANEOUS MATERIAL AND EQUIPMENT

3 pr.	Hinges, 4" leaf
2 pr.	Latches (any type available)
18	Bolts (for hinges)
As required	Screws, wood
As required	Nails
As required	Paint

LIST OF MATERIALS (Cont'd)

LUMBER

No. of Pieces	Size	Use
2	1/2" x 4" x 22" (*)	Gable of Roof
2	1/2" x 4" x 35-3/8"	2nd floor ceiling and floor of 1st floor
1	1/2" x 4" x 32-15/16"	1st floor ceiling
4	5/8" x 7" x 36"	Bottom & top of both panels
4	5/8" x 7" x 29-3/8"	Sides of both panels
As needed	1" x 2" (Lath)	For fastening back of panels

PLYWOOD

1/4" - 8 ply

No. of Pieces	Size	Use
5	4" x 14-1/16"	2nd floor partitions
2	4" x 12"	1st floor partitions
1	4" x 14-9/16"	1st floor partition
2	29-3/8" x 35-3/8"	False back (interior)
2	28-3/4" x 34-3/4"	Back of both panels

All 1/2" lumber is 5/8" stock planed to 1/2" thickness
All 5/8" lumber is 3/4" stock planed to 5/8" thickness
All plywood is 3 ply 1/4" thickness

* 22" is the overall length of the gable pieces

PARTS LETTERED ON DRAWING

A	Lamp holder and outlet box (3-1/4" x 1-1/2")
B	Range outlet
C	Convenience receptacle (boxes, 1-1/2" deep)
D	Switch, 2-way (boxes, 2" deep)
E	Switch, despard arrangement (1 SP and 1 3-way)
F	Circuit breaker panel
G	Meter socket
H	Weather head
I	Connector, cord, twist-lock (2 wire)
J	Connector, cord, twist-lock (3 wire)
K	Switch, (3-way)
L	Hinge
M	Latch
N	Lath (to support back plywood panel)
O	Non-metallic sheathed cable (3-wire)
P	Panel interlocking bolt hole
Q	Non-metallic sheathed cable (2-wire)
R	Service entrance cable
S	Ground rod clamp
T	Ground rod (cut short) and clamp
U	Ground wire
V	Sill Plate

VI. REVIEW QUESTIONS ON WIRING FUNDAMENTALS

A. These Questions to Conclude the Study of Wiring Fundamentals

1. What is the difference between a "volt" and an "ampere"?
2. What is meant by "voltage drop"?
3. What are watts and kilowatts, and what is the difference between them?
4. What is the difference between a kilowatt and a kilowatt hour?
5. What is the purpose of a fuse or circuit breaker?
6. What determines the size of a fuse or circuit breaker?
7. What is the purpose of a "ground"?
8. Is most farm current single-phase or three-phase?
9. What is the primary voltage on most REA-financed single-phase lines?
10. What is the secondary voltage used for lights? For storage water heaters?
11. What is a load center?
12. What size fuse or circuit breaker must be used on ordinary lighting circuits?
13. Why is a larger fuse or circuit breaker not permitted if No. 12 or No. 10 wire is used in the ordinary lighting circuit?
14. What is Ohm's Law?
15. What is the mathematical relationship between volts, amperes, and watts for direct current? For alternating current?
16. If the resistance of a wire is doubled while the current through it stays constant, what is the change in the heat developed in the wire?
17. If the current in a wire is doubled while its resistance stays constant, what is the change in the heat developed in the wire.
18. As the voltage across the terminals of an appliance is lowered, what happens to the capacity of the appliance to do its work?
19. Is shock the direct result of amperage or of voltage?
20. Why is the shock danger greater on a 115 volt circuit than on a 6-volt circuit?
21. The manager of an REA-financed cooperative reported that one of the members of his cooperative interchanged the feeder wires to his barn so that the "hot" wire from the house was connected to the neutral wire at the barn and the neutral wire from the house was connected to the ungrounded wire at the barn. The member complained of high bills after this change was made. What does this tell about the "ground" at the barn?
22. What are the most common causes of high resistance in farm wiring?
23. We have all known of cases where a large fuse has been substituted for a smaller correct one but no fire occurred. Did any damage to anything occur? If so, what?
24. The installation cost of circuit breakers is usually more than fuse installation costs. Would you recommend them to a farmer? If so, why?
25. Why is it undesirable to connect appliances to light outlets?
26. Is there any advantage in using three-wire 120-240 volt feeder wires to a building if only 120 volt equipment is to be used in the building?

PLANNING WIRING SYSTEMS

I. DETERMINING WHAT ELECTRICITY IS TO DO ON THE FARM

Every good wiring plan is based on the uses that are to be made of electricity on the particular farm. Knowing the probable uses involves more than an inspection of the buildings. It involves an understanding of the management and probable future management changes of the farm and home. It involves an understanding of the people living there. After all, the sole function of electric wiring is to safely and efficiently carry electricity to the places on the farm where it is to be used. For the sake of discussion we can divide the determination of what electricity is to do on the farm into the following three topics.

A. Very Common Uses

These are the uses that occur frequently enough so that they often are discussed in books, leaflets, and pamphlets on the subject of planning wiring. A person helping farm people plan their wiring should be familiar with these uses and should study literature of this type. Planning Your Farmstead Wiring and Lighting, U.S.D.A. Miscellaneous Publication 597 is such a bulletin. If a large number of farms are considered it will be found that these common uses will occur on most of them and that the recommendations in the publications are generally sound. However, they are based on buildings, not on people. When a plan is placed in a book the structure is shown and the plan is sound in those cases where the people use the structure in the usual ways and to its full capacity. The recommendations for these common uses are the most readily understood and since they are written where we can read them they require the least skill in applying.

B. Uses Peculiar to the Particular Home or Farm

These are the uses for which the wiring on the farm should digress from the usual recommendations or where unusual and rare situations are encountered. A few uses of this type are found on nearly every farm. They, most commonly, result from the fact that people are not uniform and that everyone at times makes mistakes in judgment. Since they are peculiar to the individual home or farm they must be recognized by the planner without having previously studied them in a book or bulletin. Some of them are easily recognized, as for example an invalid in bed in what would normally be the laundry and workroom of the home. Another fairly common example which is recognized only through an understanding of farm management and the particular farm is a building that is partially unsuited to the farm on which it is located and which, therefore, will never be fully used as was originally intended or to its full capacity. Obviously, it would be a mistake to wire such a building as if it were on a farm to which it was perfectly suited.

Many wiring plans are mistakenly made on the assumption that the electricity is to serve the building rather than the people. The plans described in books and leaflets are of necessity based on this type of mistake or perhaps it would be better to say that the authors, lacking other specific information, had to assume that the buildings were well suited to the farms on which they were located and to the farm families and that they would be used efficiently to their capacity. Plans are the best plans only when they fit the uses that will be made of the electricity, and these uses depend on things in addition to the structure.

- C. Uses Determined by the Individual Home and Farm Management Schemes
- Farming is largely a power operation. The amount of power per worker used on farms is greater than that in many industries. For thousands of years this power was furnished by men and animals. Then the tractor took over the power requirements for field work. But on many farms 50 to 80 percent of the work is around the buildings and doing chores. Electricity is now mechanizing this work. The changes in the home brought by electricity are well known. From this we can see that electricity has an important place in the management of the farm and home, but it is only one of many factors in this management. No two farms are managed exactly alike, but this does not necessarily mean that one is managed better than the other any more than the fact that two electric cooperatives managed differently means that one manager is better than the other. On the other hand, the excellent manager is uncommon on farms the same as he is in any other type of business. A little thought will reveal to anyone that the manager of any business, whether it be farming, commercial, or industrial, has a great influence on the amount and type of mechanization of that business. No one is able to forecast the future use of electricity on a particular farm unless he understands the management of that farm. The mere fact that it is a dairy farm having a certain number of cows and selling milk in a certain way, or a poultry farm of a certain size selling certain types of poultry products, does not give us all the information that we have to have to know the equipment that will be used.

Wiring plans in books and bulletins assume a certain management, and usually assume a very efficient management. A practical plan fitting the particular farm is based on the management that will be used on that farm which is more likely to be of an average grade than of an excellent grade. Such a plan can be prepared only when the planner has an understanding of the management. This is particularly important because no good farm manager will install wiring according to a plan which he does not accept as his own, and which he believes does not fit his situation. Considerable skill is needed in helping farmers plan wiring to fit their farming since most of them have never used electricity in farming before the original installations are made on their farms. It involves both an understanding of farm and home uses of electricity and the management of the farm and home.

II. ADAPTING THE WIRING TO THE INDIVIDUAL WORKING AND LIVING STANDARDS OF THE FAMILY

After the wiring planner knows where electricity is to be used and for what purposes, he still must determine how it will be used if his final plan is to fit the situation best. Of course, the "how" will be determined partially by the structures, by the type of farming, by special situations peculiar to that farm and home, and by the management schemes, but the individual family working and living standards are also very important. For example, two men may have very similar farming enterprises but, due to personal preference, one man may use a few large pieces of mechanical equipment while the other may use many small pieces. When they get electricity, this matter of personal preference will likely continue and affect the equipment used. One may get a large portable motor and use it on several different machines while the other may use individual motors sized to each machine. Some judgment of the situation can be made by talking to the farmer and his family, but if the family has not had extensive previous experience in using electricity in farming it is also wise to look around. There are many important things to observe, but these stand out:

- (1) Living habits - cleanliness, neatness, etc.
- (2) Relative emphasis placed by the family on family living and on farm production.
- (3) The economic level of living and farming.

A. Living Habits - Cleanliness, Neatness, Etc.

While cases are not at all uncommon in which electricity seems to have been the spark that caused a family to raise its standards of cleanliness and neatness, it would be a serious mistake to plan wiring systems generally with this expectation. Only the skills of long experience can qualify a person to judge those cases where decided improvement in these standards will likely result from the use of electricity. Attempts by the unskilled to use this method of raising these standards will most likely result in ignoring or distorting the plan when the actual wiring is done, or in failure to use the wiring as planned. An ignored plan is usually worse than none at all. It is usually best practice for the beginner in wiring planning to aim at a wiring system that will fit the family standards as he finds them unless he has very specific evidence that the family is ready to respond and adopt different standards. The wiring is part of the real property. The wiring and the electrical equipment that it serves will likely be used and receive care similar to the rest of the real property and equipment about the farm.

B. Relative Emphasis on Family Living And On Farm Production

Families differ widely, and communities differ widely, on the relative pride that they take in their family living and in their farms as businesses. Some farmers spend more of their

available resources on the family and home while others spend more on their barns, farm equipment, and other outside facilities. A farm with a ramshackle house and well kept barns and farm equipment should have more complete and elaborate wiring in the barn than a similar farm with a well-maintained house and a barn that is kept from falling over by props in the barnyard, even though the buildings are very similar in size and use and the farming operations are very similar. The well-planned wiring system will fit in with the situation as it exists.

C. The Economic Level of Farming and Living

The significance of economic level is so widely recognized that it hardly needs comment. The higher the economic level, the more luxury use and the more use strictly for convenience should be planned in the wiring. The planner should recognize that there is a limit to what most farmers will pay for wiring. Of course, a good educational program preceding the planning will have readied most farmers to pay an amount sufficient to get at least a good basic (installation) system, but this still leaves many choices to be made. For example, one farmer may be willing to pay for several yard lights controlled by 3-way and 4-way switches at each building on the farmstead while another farmer with a similar building arrangement may be willing to pay for only one yard light controlled from only the major buildings. It may be necessary to choose between an individual light over the kitchen work space and a 3-way switch somewhere in the house. The choice may be between a ceiling light fixture in the living room and one or more additional convenience outlets along the wall. Where choices of this type must be made, it is necessary to carefully evaluate the probable usefulness of each item. It is a matter of expert skill and judgment to know how to fit the wiring plan to the economic level of the farm and family, so that the wiring will provide the greatest usefulness of electricity and still come within the price range that the family can and will pay,

Throughout the planning of all farm wiring it should be remembered that no plan is worth preparing unless when it is finished it is the family's plan. A great part of the skill of a good planner is his ability to get the family to think through accurately its future uses of electricity and to understand the amount and layout of the wiring necessary to provide for the uses adequately. Few families will hire electricians to install wiring according to plans that they do not understand, fully approve of, and want. A plan that is not used is a waste of time, effort, and materials.

III. PLANNING THE LOCATION OF OUTLETS

When we know what the electricity is to be used for, and when we know how it is to be used, we then are in a position to plan the location of outlets. There are some situations that occur so frequently that certain standard recommendations are consistently made in literature on wiring planning. For example, convenience outlets in the living room should be spaced at intervals around the wall such that the cord of a floor lamp placed anywhere along the wall will reach an outlet without an extension. These standard recommendations are found so frequently that very careful thought should be given to a situation before digressing from them. Usually careful consideration will show that the impulse to digress was wrong. But then we do find cases occasionally where the best plan requires a different location. An instance of this type might exist where the wiring is done in the autumn and the farmer is planning and has arrangements all made to remove a wall during the coming winter. In general convenience outlets should not be placed so that cords from them will cross or obstruct paths of travel, but there are even exceptions to this rule. If the outlets where housewives use their electric irons were all placed so that the women would have to unplug the irons when they leave their ironing boards, many fires would be prevented.

Although good planning does occasionally require exceptions to most of the standard recommendations, most of the exceptions that are made in practice are the result of poor planning. It is far more important that the outlet that serves table appliances on the dining table be placed so that the cords to the appliances cross the space where the housewife, in serving, normally reverses her travel around the table than that it be placed opposite an outlet on the other side of the wall so that the electrician's work in installing it is easier. A little thought will reveal that if the outlet for the chick brooder is on or suspended from the ceiling there will be less probability that the chicks will roost on the cord or that it will be in the way of a person working around the brooder.

There are many good sources of recommendations on the location for outlets. Here are a few:

1. Planning Your Farmstead Wiring and Lighting, U.S.D.A., REA, Miscellaneous Publication 597.
2. Electric Wiring For Home Or Farm - How to Plan It - How to Install It, Sears Roebuck & Company.
3. Farm Wiring Guide, General Electric Company, Appliance & Merchandise Department, Bridgeport, Connecticut.
4. Farm Wiring Needs, TVA, Division of Electrical Development, Chattanooga, Tennessee.
5. Farmstead Wiring, Westinghouse Electric Corp., East Pittsburgh, Pa.
6. Handbook of Farmstead Wiring Design, Industry Committee on Interior Wiring Design, Room 2650, 420 Lexington Ave., New York, N. Y.
7. Handbook of Residential Wiring Design, Industry Committee on Interior Wiring Design, Room 2650, 420 Lexington Ave., New York, N. Y.
8. College Extension Bulletins.

IV. BASIC WIRING

Basic wiring might be described as the backbone of the ultimate wiring system. Few farmers install their complete ultimate systems at first. There are many reasons for this. Some of the reasons are good; others are questionable. But regardless of the quality of the reasons, good planning recognizes the fact. Perhaps the three most common are:

1. Immediate high cash cost.
2. Some uses of electricity appear to be so far in the future that the investment in the wiring for them should be delayed.
3. Questionable accuracy in forecasting future uses of electricity.

Since initial installations are rarely the ultimate systems, one of the most important considerations in a good plan is the determination of what is to be installed immediately - the basic wiring. If the basic wiring is carefully planned and properly installed, future additions can be added to it with the sound expectations that the equipment connected to the additions will function properly. If the basic wiring is not carefully planned and properly installed future additions may require replacing portions of the initial wiring or may not provide for best use of the equipment.

Often the good planner will prepare a very complete plan, regardless of the cost of the wiring job involved. He will then trim this plan until it comes within the limitations of what the family is ready to put in. What he has left is the basic wiring for that farmstead. Then when the electrician does the wiring he will install the basic wiring, but he will also have in mind the ultimate system and will size and arrange parts so they will fit the ultimate system.

Load centers and feeder wires are particularly important. They are comparatively expensive parts of the system. Many farmers hesitate to discard and replace them with more expensive parts when additions are made, but if the planning had been good at first, and the larger parts installed then, the extra cost of the initial wiring would have been small.

In most parts of the country, practically all farms should have 3-wire service entrances. Many farms need 100 ampere entrance switches and a few need even larger ones.

V. DEVICES FOR TEACHING PLANNING TO GROUPS

The electrification adviser will not have time to personally supervise the planning of many individual farm wiring systems. If he did nothing else, and assuming that someone else did the general educational work that must precede the actual preparation of plans, he would be unable to supervise the planning and prepare plans for use by electricians for more than 8 to 10 farms a week. However, he should do some of this work. There are 3 reasons for this:

1. He needs demonstrations for use in his group teaching. He should supervise and assist with the planning on demonstration farms.
2. If his teaching is to be effective, he must have first-hand familiarity with the process and problems of planning.
3. He will need basic local material to use in teaching planning to groups. Ordinarily, he can get this material only by personally participating in actual planning.

Since the greatest part of the electrification adviser's work on wiring planning will be teaching groups how to plan their own individual systems, he will need to have and be able to use various teaching devices.

A. Wiring Plan Charts and Work Sheets

Wiring plan charts are among the most common and most useful devices for teaching wiring planning. Usually they show the floor plans of buildings and the arrangement of buildings on the farmstead with symbols to point out the locations of various outlets. Together with work sheets they provide a means of illustrating where outlets should be placed, the types of outlets to fit different situations, and a method that farmers may use to prepare and evaluate their own plans. Small charts may be duplicated in quantity and distributed among the group so that each person has one to look at as he follows the discussion. The speaker often needs large charts which the whole group can see and on which he can point out special features.

The usual charts are printed or drawn on paper. Each chart shows one arrangement. Several are required to show several arrangements, and they can show only arrangements that have been selected long enough in advance to give an opportunity to prepare the charts.

Every electrification adviser needs a supply of charts representing typical situations in the area served by his co-op. Some of these may be taken from plans shown in literature, but the best ones will show actual local situations.

B. Flannel Charts

Flannel charts are very useful in many meetings. Such a chart consists of a piece of flannel cloth which is hung on the wall, and an assortment of symbols each drawn on individual pieces of

paper and pasted to small pieces of flannel. When the symbols are placed on the large piece of cloth with the flannel of the symbols against the cloth, they will adhere to the background until picked off. This makes a convenient arrangement for adding and taking off symbols or moving them from one location to another. Sometimes the floor plan of a building is drawn directly on the flannel background. In other cases symbols representing sections of walls, doors, windows, etc., are used so that different room arrangements can be created on the charts as they are shown before groups. This permits the instructor to use the floor plan of a person in the group as his example.

C. Slides, Film Strips, and Movies

Lantern slides, film strips, and movies are useful teaching devices that also provide an entertainment element in rural meetings. They are good for presenting general plans. They are less useful for presenting localized information. They have the advantage of usually being attractive to the group, and if well shown are clearly seen by everyone. Their biggest disadvantage is that their preparation requires considerable time, skill, equipment, and money. Most electrification advisers will not have the time or facilities to prepare good slides, film strips, or movies for their own use. They will therefore be limited to those that they can buy, rent, or borrow from other sources. There are not many good ones on the subject of planning wiring that are generally available. In general, they are better adapted than such devices as charts to use in meetings with large groups, but they do not lend themselves as well as charts to discussions of personal problems.

D. Planning Booklets

No electrification adviser can give a great deal of personal service to members of his cooperative in planning their individual wiring systems. There are some members that will not even attend his meetings. Those that do still need help when they go home and study their own problems. Planning booklets offer a means of reaching additional people and providing those that attend meetings with material to study at home. These booklets alone, of course, are not as adequate as personal service and discussion in meetings, but they do provide a means of reaching more people and of extending group teaching. They give general recommendations which can be of great help. They cannot give the answers to individual peculiar problems. Sometimes the absence of these special answers breaks down the members' reliance on such booklets as a sound guide. In using them, the electrification adviser should show the members of his cooperative the general soundness of the recommendations given so that when they meet their own special problems their confidence in the whole booklet is not destroyed. A list of several good planning booklets has already been given under PLANNING THE LOCATION OF OUTLETS.

E. Demonstration Scripts

Various organizations at one time or another have prepared demonstration scripts for use in different phases of power use teaching. Usually these scripts have been prepared for special types of occasions and after use for a limited period of time are no longer available. If such a script is available to the beginner in teaching wiring planning it might be quite useful to him. However, talks prepared to fit the individual local situation are usually superior. Experienced teachers seldom use these prepared scripts except when they are first showing a film strip or a series of slides with which they are not familiar.

VI. PREPARING AND USING WIRING PLANS

Electrification advisers need prepared wiring plans in teaching the planning of wiring systems. These plans are usually used in chart form but may also be lantern slides or on film strips. In many group meetings they are the best substitute for actually looking at installed systems.

The plans published in books and leaflets are useful, particularly in teaching general principles, but in many situations plans of locally installed systems are best. It is likely that the electrification adviser will have to prepare these local plans. In order to do this, he must know the techniques of preparing and reproducing them. He must also be prepared to recommend to farm families methods and techniques which they can use in doing their own planning.

A. Use of Cross-Section Paper

The best wiring plans for existing buildings are made on the site of the wiring. If the electrification adviser is to use the plan in his teaching he must draw it up while on the farm. Farm families are also in the best position to deal with the electricians who wire their places if they have drawn plans of their personal systems.

The most practical means of preparing the rough drawing of a plan uses cross-section paper. Almost any cross-section paper may be used; one with 4 squares to the inch is very good.

The floor plan of each building and the arrangement of buildings on the farmstead can easily be outlined using a separate sheet of paper for each floor of each building and for the whole farmstead. In drawing the floor plans of buildings, it is usually convenient to let $1/4$ inch on the paper represent 1 foot in the building. If paper with 4 squares to the inch is used, one square on the paper would represent 1 foot in the building. A different scale, depending on the size of the farmstead, will be necessary for showing the arrangement of the buildings.

When the buildings are sketched on the paper it is a simple matter to show the locations of each of the separate planned outlets and of the wires between buildings by appropriate symbols. These plans do not need to show the location of wires in circuits since that is a matter for the electrician to decide when he does the wiring.

B. Conventional Symbols and Their Use

Almost any symbols that are clear to the electrification adviser and the farmer may be used on the rough sketches of plans drawn on the sites, but when the plans are reproduced for showing to groups it is desirable to use symbols that are generally used and widely recognized.

While the symbols used in published literature have varied somewhat, some very common ones are shown on page 5 of U.S.D.A Miscellaneous Publication 597, Planning Your Farmstead Wiring And Lighting. Much broader assortments of symbols will be found in the Handbook of Farmstead Wiring Design, Industry Committee on Interior Wiring Design, and in planning booklets by various commercial companies and state colleges.

C. Preparing Plans For Reproduction

Plans to be shown to groups need to be neatly and clearly prepared. The electrification adviser may need only one set of large plans that are clearly visible before a large size group, but if he uses plans drawn on ordinary notebook size paper he will need to have them reproduced in considerable quantity. He is even likely to need more than one set of large sized ones, particularly if he is cooperating with other educational people in the cooperative's area who may borrow plans.

Obviously the rough sketches prepared on the sites where the planning is done are inadequate. Using the rough sketches as guides, the electrification adviser personally may have to draw up the plans in finished form. This does not require architectural or professional drafting training but it does require some care and patience. It does not require elaborate drafting equipment although such equipment may be used if it is available. It does require a hard, smooth, well-lighted surface on which to work. A desk top will serve. It requires a ruler with a straight edge, pencils, erasers, drawing ink, a ruling pen, and a compass. A small drawing board with a T-square and two celluloid triangles, one with 30 degree and 60 degree angles and the other with 45 degree angles, would be very helpful. A piece of ground glass with a light under it makes an excellent drawing board for use in copying drawings. The original drawing is placed on the glass and the paper to which it is to be copied is placed on it. When the light under the glass is turned on, the drawing to be copied becomes clearly visible.

Clearness is the most important thing in the lettering. The beginner is likely to avoid lettering on his drawings because he fears that he cannot do a professional looking job. He should cast these fears aside because if his lettering is reasonably neat and legible it will be thoroughly acceptable. With a little practice anyone can do acceptable lettering. Most people find it best to draw light parallel lines with a pencil which the tops and bottoms are to touch. Then the letters are drawn in lightly with a pencil. After they have been drawn, erased, and redrawn until they are about as wanted, they are inked in, and the pencil lines are erased. The beginner should watch the size of his lettering. If the plan is drawn large and then reduced in size in reproducing, the size of the letters will also be reduced. They must be large enough to be clearly visible in the final reproduction.

D. Ways of Reproducing Plans

There are a wide variety of ways of reproducing drawings of plans. No one of these meets all needs.

Small plans are often reproduced by mimeographing. This is a cheap method and is satisfactory for many purposes. However, there is danger of not getting clear reproduction. Considerable care should be used in preparing the stencils. The sketch of the plan must be drawn directly on the stencil, but unless it is drawn by an expert it had better be drawn on paper first and then copied on to the stencil by using ground glass with a light under it for a drawing board.

If blueprinting or other of the conventional architectural duplicating methods are available they may be used. They require that the plan be drawn on special paper. The reproducing process then transfers the plan from this drawing to finished paper.

Various photographic processes such as photostating and multi-lithing may be used. These processes reproduce very clearly and they usually provide for either enlarging or reducing the size of the drawing, as desired. The original drawing for these processes is prepared on ordinary white paper.

Plans may be reproduced by ordinary printing such as is used for newspapers and magazines. The size may be increased or reduced by this process. The drawings are first prepared on white paper.

The electrification adviser should remember that enlarging a drawing emphasizes its irregularities and defects while reducing its size tends to conceal them. It is wise, whenever possible, to make the original drawing large and then to reproduce it at that same size or smaller.

E. Locating Outlets With Chalk Or Cards

The methods described above are useful primarily to the electrification adviser in his work in teaching wiring planning to groups. When planning is done to help a single family or when the family itself does its own planning, other techniques are commonly used. It is best for the family to actually make a rough sketch of its wiring plan on cross-section paper, but many families will not take the time to do this. A substitute scheme that has worked quite well in planning for the house only is to mark on the walls the proposed location of outlets.

There are several ways of marking locations on walls. One is to use chalk. Another is to attach cards with pins or tacks. Regardless of the method of marking, this system is a way of assuring that there is understanding between the family and the electrician as to number and locations of outlets when negotiations are under way and when the wiring is done.

VII. METHODS OF ESTIMATING WIRING COSTS

When the electrification adviser is helping farm people plan their wiring he is always faced with the problem of helping them estimate what the completed wiring will cost if the plan is followed. The methods of estimating costs are quite well known and do not need much elaboration here. The two most common methods are:

- (1) By the outlet plus service entrance and outdoor span costs.
- (2) By labor and material costs.

Many cooperatives have negotiated with the wiremen in their areas and established uniform reasonable wiring prices. These prices are usually on a basis of a certain amount for each type of outlet, a certain amount for each type of service entrance installation, and a price on outdoor wiring spans that depends on the wire size and length. Where these established prices are in effect, an estimate of the wiring cost for a certain farm is arrived at by merely adding together the costs of the outlets, entrance equipment, and wire spans involved. Even where agreements are not in effect between the cooperative and the wiremen, many wiremen use this method of arriving at prices to quote and the prices used are well known in the community.

When the common wiring prices on a unit basis are not known, a good estimate can be reached by adding together the cost of materials, adding to this a fair wage for the wiremen based on the time needed to make similar installations, and then adding to this a fair profit of possibly 30 percent to 40 percent of the sum of the material and labor costs. The first few installations that an electrification adviser figures in this way may take considerable time, but he will soon learn to estimate materials in groups and the labor by the size of the job and will be able to make sufficiently accurate estimates in a few minutes.

VIII. HELPING A FARM FAMILY PLAN ITS WIRING

No two people will approach the problem of helping a farm family plan its wiring in exactly the same way, but the methods of experienced persons can be very helpful to a beginner. The essential elements in good planning have already been discussed. Those elements can be summarized in the statements:

- (1) Electricity serves people - not buildings.
- (2) The wiring must serve equipment economically, efficiently, and safely.
- (3) The plan must be the family's plan if it is to be followed.

No good plan is prepared without active participation of the farm family. For this reason it is best to schedule the planning in advance so that the members of the family will have been thinking about it and will be present.

When the electrification adviser reaches the farm it is good to talk informally with the family for a while. In casual conversation much can be learned about its plans, hopes, and aspirations. It is good to walk informally over the farmstead, observing the buildings, equipment, and standards of farming and living as revealed by what is visible. The furnishings and housekeeping standards in the home should be noted. During this time a judgment can be reached of something of the nature and extent of a wiring system that will fit.

It should be made clear to the family that no prepared plan has been brought to the farm - that the plan is to be "tailored to fit" right there - and that the family, not the electrification adviser, is to be the judge of the fit.

The electrification adviser will want to sketch on cross-section paper the building arrangement on the farmstead and the floor plans of each building.

When these preliminary arrangements and discussions are completed, the experienced electrification adviser will have a good idea of the nature of the wiring system that should be installed and the family will be ready to enter whole-heartedly into the planning.

An excellent method is to go through each room of each building, discussing what electricity is to be used for and how it is to be used in each. When the nature of the use in each room has been decided, the types and locations of outlets to best meet the need should be planned. As the type and location of each outlet is determined, it should be marked on the floor plan sketches that have already been prepared. Much of the electrification adviser's planning skill is needed in helping the family to think through its future use of electricity at each place in each room and in helping it see the need for the proper types of outlets located so as to serve these uses efficiently.

Often the detailed planning starts in the living room. The discussion could start around the present furniture arrangement and the probable location of lamps, radios, and other equipment as revealed by the furniture as it is. This would be followed by a discussion of probable changes in arrangement, by the effect of special occasions such as Christmas with the tree to be lighted, and by the probable use of luxury devices such as lighting brackets by the mantel. Each room in the house and in each other building would be analyzed in detail in this fashion. Then the outdoor lighting and outlets for outdoor use of other equipment would be similarly analyzed and the locations of outlets marked on the prepared sketches.

When all of the locations for outlets have been carefully analyzed and the final choices plotted, the locations of load centers to best serve the outlets should be determined and marked on the sketches.

If the ultimate uses of electricity have been properly considered, it will likely be necessary to sit down with the family and discuss the probable costs. If the whole system is not to be put in at once, it will be necessary to analyze the probable first uses and the relative usefulness of various planned outlets to determine the initial installation. The selections for the initial installation should be clearly marked on the sketches.

If the rough sketches are to be left with the family for use in its negotiations with the wireman, the electrification adviser should place on the sketches a clear key to the symbols that he has used.

If the electrification adviser is going to use the plan in his group teaching, he will want to take the rough sketches with him so that he can use them in preparing his drawings for display. In this case he would send back to the family a carefully drawn plan for its use.

THE WIRING

I. Sources of Information on Materials and Technique

Standards and specifications for safe wiring are given in the National Electrical Code. Before attempting to discuss or demonstrate wiring design and installation practices, we should become familiar with standard requirements, methods, and materials. It is not the intention of this section to incorporate in detail all of the material necessary, but only to cover the basic principles on which further detailed study may be made. Useful information may be found in the following and other reference material:

- (1) "National Electrical Code", - Standard of the National Board of Fire Underwriters.
- (2) "National Electrical Code Handbook", - By Arthur L. Abott, McGraw-Hill Book Company, Inc., New York, New York.
- (3) "Specifications for Farmstead Wiring", Form AL-23R - Rural Electrification Administration.
- (4) "List of Inspected Electrical Equipment", - Underwriters' Laboratories, Inc.
- (5) "Rural Electrification", - by J. P. Schaenzer, Bruce Publishing Company, Milwaukee, Wisconsin.
- (6) Extension Publications from State Colleges.

II. Wiring Design and Protection

Other sections have discussed "Planning Wiring Systems", which we might say is the farmers' responsibility. We would like to highlight a few of the points dealing with the responsibility of the electrician in making installations and some of the things with which the adviser should familiarize himself in teaching and checking good wiring.

The REA recommended "Specifications for Farmstead Wiring", Form AL-23R, emphasizes portions of the National Electrical Code which have a particular application to rural wiring. It also suggests mandatory consideration of certain rules which are written in the Code only as recommendations. The "Specifications" we might say are a standardization or interpretation and grouping of main points of the "Code."

Before any electrician should attempt to make a wiring installation, he should become familiar with the branch circuits, feeders and service entrance requirements, overcurrent protection and grounding requirements, as set forth in Articles 200, 210, 220, 230, 240, and 250 of the Code. It may be well to make a brief breakdown of the various articles of Chapter 2 of the National Electrical Code.

A. Polarity Identification of System and Circuits

Polarity has sometimes been confusing to wiremen in that they are still thinking in terms of direct current. In D. C. we have the current flowing in one direction with one positive wire and one negative wire. In A. C. we have the two wires, one being hot and the other neutral. For our purposes, then, we will think of polarity as maintaining a fixed difference of potential between the two wires of a circuit. We have a color code in wiring to assist in making installations or inspections to assure us that polarity is maintained. Care should always be taken to see that the black wire follows through the entire circuit and is always connected to the hot side of the socket. It is the one that is broken through switches. In a like manner the white or neutral wire should always be connected to the shell of the socket and never broken by a switch. In the event that it becomes necessary to inspect an old system where two black wires are used, it will be necessary to check the polarity by "ringing out" the circuits.

B. Branch Circuits

Reference for planning and installing branch circuits may be obtained from Sections 2113 to 2127 inclusive of Article 210 of the National Electrical Code and from paragraph 5 of Form AL-23R.

First it should be noted that the minimum requirement for any dwelling is at least one 15 ampere branch circuit and one 20 ampere branch circuit. In most cases, however, this will not be adequate. The Code further specifies that a minimum of No. 14 AWG wire be used with the 15 ampere lighting and appliance circuit, and that one such circuit be provided for each 500 sq. ft. of floor area. Regardless of the size of wire used in the circuit no larger than 15 ampere fuses shall be used if lighting fixtures are attached to it. This is because the fuse must protect the wires in the fixtures as well as those in the circuit. The small appliance circuits, (20 ampere) are installed with a minimum of No. 12 AWG wire and should provide for the small appliance loads in the kitchen, laundry room, pantry, back porches, basements, and dining rooms of all dwellings. A minimum of one outlet for each room is required with further recommendations that an outlet be provided on the 20 ampere circuit for each 20 linear feet of the total (gross) distance around the room measured horizontally along the wall at the floor line. An often-used, good rule-of-thumb is to limit the number of outlets on any circuit to 8 or, as a maximum, 10. Other special circuits such as the range, water heater, water pump, and motor circuits will depend on the manufacturer's rating of the equipment. Form AL-23R, paragraph 5, specifies that the branch circuit to the range be not less than 3 No. 6 AWG wires. Branch circuits to water heater outlets are to be two wires not smaller than No. 12 AWG. Wire sizes and protection for motor circuits shall be in accord with the provisions of Table 20, Chapter 10, of the National Electrical Code. This table is for not more than 3 percent voltage drop. On lighting circuits the voltage drop should not exceed 1 percent. The following tables show the necessary wire sizes for various length runs to maintain voltage drops of not more than 1 percent and 3 percent.

SIZE OF WIRE NEEDED TO PREVENT MORE THAN A 1 PERCENT
VOLTAGE DROP
115 VOLTS

DISTANCE ALONG ROUTE OF THE WIRE	ELECTRICAL LOAD (AMPERES)																				DISTANCE ALONG ROUTE OF THE WIRE
	1 AMP.	1½ AMPS.	2 AMPS.	2½ AMPS.	3 AMPS.	4 AMPS.	5 AMPS.	6 AMPS.	7 AMPS.	8 AMPS.	9 AMPS.	10 AMPS.	11 AMPS.	12 AMPS.	13 AMPS.	14 AMPS.	15 AMPS.	16 AMPS.	17 AMPS.	18 AMPS.	
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NOTE: No consideration given to voltage drop.

NOTE: No consideration given to wires smaller than No. 18 since they are commonly used only for special purposes

NOTE: This chart does not show wire sizes needed to protect the wire insulation from heat (Consult the National Electrical Code for these sizes.)

SIZE OF WIRE NEEDED TO PREVENT MORE THAN A 1 PERCENT
VOLTAGE DROP
230 VOLTS

DISTANCE ALONG ROUTE OF THE WIRE	ELECTRICAL LOAD (AMPERES)																																																		DISTANCE ALONG ROUTE OF THE WIRE
	1 AMP	1 1/2 AMPS	2 AMPS	2 1/2 AMPS	3 AMPS	4 AMPS	5 AMPS	6 AMPS	7 AMPS	8 AMPS	9 AMPS	10 AMPS	11 AMPS	12 AMPS	13 AMPS	14 AMPS	15 AMPS	16 AMPS	17 AMPS	18 AMPS	19 AMPS	20 AMPS	21 AMPS	22 AMPS	23 AMPS	24 AMPS	25 AMPS	26 AMPS	27 AMPS	28 AMPS	29 AMPS	30 AMPS	31 AMPS	32 AMPS	33 AMPS	34 AMPS	35 AMPS	36 AMPS	37 AMPS	38 AMPS	39 AMPS	40 AMPS	41 AMPS	42 AMPS	43 AMPS	44 AMPS	45 AMPS	46 AMPS	47 AMPS	48 AMPS	
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NOTE: No consideration given to wires smaller than No. 10.

NOTE: No consideration given to wires smaller than No. 18 since they are commonly used only for special purposes.

NOTE: This chart does not show wire sizes needed to protect the wire insulation from heat (Consult the National Electric Code for these sizes)

SIZE OF WIRE NEEDED TO PREVENT MORE THAN A 3 PERCENT VOLTAGE DROP 115 VOLTS

DISTANCE ALONG ROUTE OF THE WIRE	ELECTRICAL LOAD (AMPERES)																				DISTANCE ALONG ROUTE OF THE WIRE
	1 AMP.	1½ AMPS.	2 AMPS.	2½ AMPS.	3 AMPS.	4 AMPS.	5 AMPS.	6 AMPS.	7 AMPS.	8 AMPS.	9 AMPS.	10 AMPS.	11 AMPS.	12 AMPS.	13 AMPS.	14 AMPS.	15 AMPS.	16 AMPS.	17 AMPS.	18 AMPS.	
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NOTE: No consideration given to wires smaller than No. 18, since they are commonly used only for special purposes.

NOTE: This chart does not show wire sizes needed to protect the wire insulation from heat (Consult the National Electrical Code for these sizes.)

SIZE OF WIRE NEEDED TO PREVENT MORE THAN A 3 PERCENT VOLTAGE DROP 230 VOLTS

DISTANCE ALONG ROUTE OF THE WIRE	ELECTRICAL LOAD (AMPERES)																														DISTANCE ALONG ROUTE OF THE WIRE																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
	1 AMP	1 1/2 AMPS	2 AMPS	2 1/2 AMPS	3 AMPS	4 AMPS	5 AMPS	6 AMPS	7 AMPS	8 AMPS	9 AMPS	10 AMPS	11 AMPS	12 AMPS	13 AMPS	14 AMPS	15 AMPS	16 AMPS	17 AMPS	18 AMPS	19 AMPS	20 AMPS	21 AMPS	22 AMPS	23 AMPS	24 AMPS	25 AMPS	26 AMPS	27 AMPS	28 AMPS		29 AMPS	30 AMPS	31 AMPS	32 AMPS	33 AMPS	34 AMPS	35 AMPS	36 AMPS	37 AMPS	38 AMPS	39 AMPS	40 AMPS	41 AMPS	42 AMPS	43 AMPS	44 AMPS	45 AMPS	46 AMPS	47 AMPS	48 AMPS	49 AMPS	50 AMPS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
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NOTE: No consideration given to wires smaller than No. 18 since they are commonly used only for special purposes.

NOTE: This chart does not show wire sizes needed to protect the wire insulation from heat (Consult the National Electrical Code for these sizes.)

C. Load Centers and Overcurrent Protection

Load center capacities are determined by using the rules in Article 240 of the National Electrical Code and paragraph 3, Form AL-23R. Except in special cases, the size of overcurrent protection for conductors depends on their current carrying capacities, as given in Tables 1 and 2, Chapter 10, of the Code. Care should be taken in selecting the load center so as to not only provide for the system as now being installed, but also for future additions. It is recommended that at least two blank branch circuit connections be provided in the load center for future growth.

The location of the load center is another important factor to be considered. In most instances where the load center is located at the house, we will find that a place near the kitchen will be desired so as to be as near as possible to the heavy current consuming equipment such as ranges and water heaters. If several buildings are to be served, the load center should be located on a yard pole. We should locate the pole as close to the heavier loads as possible. Those circuits requiring only 115 volts for the operation of connected loads should be divided between the two sides of a three-wire service so that a balance of the load may be obtained with a minimum flow of current through the neutral feeder or service conductor. This enables the cooperative to deliver a maximum of current through its transformer, and reduces the voltage drop in the wiring system. Before finally locating the load center we should determine whether or not the location relative to the high-line poles is satisfactory for connection to the transformer.

It will be well for any electrification adviser to familiarize himself with these materials and methods so that he may be able to identify proper as well as improper methods of installation and to inform wiremen as well as members.

D. Services, Feeders and Service Drops

References for this section may be obtained from Articles 220 and 230 of the Code and from paragraph 3 of Form AL-23R. Service entrance wires shall be sized in accord with the "Code" specifications, but in no case shall be smaller than No. 8 AWG. No more than one 15 ampere and one 20 ampere branch circuits may be connected to 2-wire, No. 8, 30 ampere, 110 volt service entrance equipment. Where the load requires the use of a 3-wire service, No. 6 conductors shall be the minimum size. More and more cooperatives are using 3 No. 6 wires as a minimum for all installations. Care must be taken to plan for an adequate service based on the load to be served. As stated in Form AL-23R, services for outbuildings must also conform to "Code" standards.

In planning for feeders and service drops sizes and types of materials must be carefully determined. Size may be determined as covered in previous sections so as to conform to the Code recommendations.

E. Grounding

Recommendations for grounding are given in Article 250 of the Code and Paragraph 4 of Form AL-23R. The specifications recommend that the ground is to be not less than No. 6 copper wire connected to the overhead neutral by wire holders and run continuous to the grounding electrode. This recommendation is made because of the high susceptibility of rural lines to lightning surges. By connecting the ground in this manner, surges through the service equipment and meter base are kept to a minimum. Grounding for outbuildings should be the same as for the main entrance.

In many instances, too little consideration is given to the grounding of equipment. Recommendations of the "Code" should be followed carefully. It is best to have all stationary equipment grounded. Particular care should be given to equipment in damp and wet places. In all cases, use material and methods as specified in Form AL-23R and the "Code."

III. Types of Wiring Materials and Their Uses

Wiring methods and materials are covered in Chapter 3 of the "Code" and paragraph 6 of Form AL-23R. As in other sections, we will not attempt to cover this subject in detail but the electrification adviser should thoroughly familiarize himself with approved types of materials. "List of Inspected Materials", Underwriters' Laboratories, Incorporated, is an excellent guide. New approved materials are constantly being produced by which we may improve and simplify installations.

In general, we use open wiring, concealed knob and tube, armored cable, nonmetallic sheathed cable, service entrance cable, and nonmetallic waterproof wiring for farm work. Paragraph 6 of Form AL-23R specifies that all snap switches shall be tumbler or toggle type with double wipe contacts and shall be of noncompetitive grade. Snap switches controlling lighting loads shall also have "T" rating. All convenience receptacles shall be duplex type medium range, noncompetitive grade and shall have strong double wipe contacts. All switch and receptacle plates should be, and in bathrooms, kitchens, basements, and outbuildings, shall be, of nonmetallic material.

The electrification adviser must be in a position to render assistance and advice to the farmer in the use of proper materials. This is especially true when additions are made to existing systems. Far too often the improper use of lamp cord has resulted in personal injury and to improper operation of equipment.

IV. Rules and Regulations

We have been thinking in terms of the National Electrical Code as a guide for our wiring. We should investigate all state and local sources for codes or rules that would apply locally.

V. Inspection and Reinspection

In far too many instances the true meaning of inspection is not known. No electrician, no matter how good he may be, is infallible. One of the reasons for having an inspection program is to discover the honest as well as the dishonest and incompetent mistakes. On cooperatives where inspection is looked upon merely as a police job, we find that both wiremen and members are hostile to the program. Good inspection protects both contractor and member. It is also valuable in that it assures the cooperative that the system is safe for connection to its distribution lines. In many cases trouble calls and low voltage complaints could have been averted had the system been properly inspected.

Good inspection assures the member that his wiring installation:

- A. Is safe to life and property;
- B. Will permit satisfactory and safe operation of equipment which the wiring has capacity to handle;
- C. Will serve effectively and satisfactorily through a reasonable span of time without need for replacement.

The need for reinspection is increasing as installations grow older. In many instances additions which have not been inspected have been made to the systems, and in other cases, the systems have become overloaded to such extents that rapid deterioration of wire insulation is taking place.

A reinspection by a capable, conscientious inspector with a report to the member is a good form of insurance for the member. Members of a number of cooperatives have voluntarily requested a regular recheck of their wiring systems at intervals of not more than two years. When rural users of electricity become fully aware through education of the benefits of a good inspection program, they will request it rather than accept it as something which has been thrust upon them.

VI. Methods of Inspection

Few electrification advisers will be the authorized inspectors for their cooperatives. However, inspection is so important to the adviser's work and so closely related to it that the adviser should understand inspection methods practically as well as the inspector does. A reinspection program is desirable, but even this is not a substitute for advice to members on additions to their existing wiring systems. Basic techniques should be studied, then followed by practice inspection sessions on pre-selected farms with the consent of the families occupying the premises. Each trainee should be required to make his own records and to use the testing equipment until

familiar with the procedure. A good electrical inspection should determine:

- (1) That the installation is safe and of adequate capacity for the intended uses.
- (2) That the work is good mechanically and is electrically secure.
- (3) That the installation will meet the insulation resistance breakdown, polarity identification; circuit usage, and short circuit requirements of the National Electrical Code.
- (4) That the grounding resistance is within the 25 ohm maximum limitation of the "Code" or as nearly so as is possible under local soil conditions.
- (5) Finally, that the installation meets the expectation of the user as shown in his plans and specifications whenever an opinion is requested.

The above testing may be accomplished by use of any recognized standard testing set for electrical wiring systems. The test for grounding installations should be made with the same or similar type instrument as is used by the cooperative when testing line grounds.

Frequent trips with the regular electrical inspector should acquaint the electrification adviser with all practiced methods and procedures for conducting a good inspection.

